DWR/USBR
2001 Level-of-Development Benchmark Study
Version BST_2001D10A_ANNBENCHMARK_1_1
(ANN)

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California Department of Water Resources,
Bay-Delta Office
And
United States Bureau of Reclamation, Mid Pacific Region
Division of Planning

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I Introduction

This document summarizes the DWR/USBR jointly developed 2001 Level-of-Development Benchmark Study, BST_2001D10A_ANNBENCHMARK_1_1, using The California Department of Water Resources ANN Salinity Model for representing Delta flow-salinity relationships.

The model applied in developing this study is the joint DWR/USBR operations planning model, CALSIM II. The CALSIM Water Resources Simulation Model application 1.2.2 was used to run this study. The latest model application is available for downloading at http://modeling.water.ca.gov/branch/computer_models.html.

This study has been developed under the oversight of the CALFED/DWR/USBR Technical Coordination Team.

CALSIM II is a general-purpose planning simulation model developed by DWR and USBR for simulating the operation of California's water resources system, specifically the CVP and SWP. On a monthly time-step, CALSIM II utilizes optimization techniques to route water through a network. A linear programming (LP)/mixed integer linear programming (MILP) solver determines an optimal set of decisions for each time period given a set of weights and system constraints. A key component for specification of the physical and operational constraints is the WRESL language. The model user describes the physical system (dams, reservoirs, channels, pumping plants, etc.), operational rules (flood-control diagrams, minimum flows, delivery requirements, etc.), and priorities for allocating water to different uses in WRESL statements.

It is intended that CALSIM II be used in a comparative mode. The results from a "With Project" alternative simulation are compared to the results of a Benchmark simulation to determine the incremental effects of a project. The results from a single simulation may not necessarily represent the exact operations for a specific month or year, but should reflect long-term trends. The model should be used with extreme caution to prescribe seasonal or to guide real-time operations, predict flows or water deliveries for any real-time operations.

II Key Model Results for Benchmark Study Version BST_2001D10A_ANNBENCHMARK_1_1 (ANN)

This section presents key results regarding project water supply capabilities, project operations as well as CVPIA (b)(2) and EWA operations as simulated by the model.

II.1. Water Supply

Table II.1.1
Water Supply (2001 LOD Benchmark Study)
(taf/year)

Delivery	(May 1928 - Oct. 1934) Dry Period Average	(1922-1994) 73-Year Period Average
SWP South-of-Delta Firm Delivery	1875	2962
SWP Interruptible Delivery	66	134
CVP North-of-Delta Delivery	2077	2211
CVP South-of-Delta Delivery **	1678	2482
CVP South-of-Delta Ag Delivery **	345	1011
Total Delivery	5697	7789

** Note: Cross Valley Canal Users not included

Table II.1.1 shows the average annual deliveries for the SWP and CVP for the historical dry period of 1928 through 1934 and 73-year long-term. The average annual SWP south-of-Delta firm delivery in the dry period of 1928 through 1934 is 1875 taf and 2962 taf long-term. The average annual SWP interruptible delivery in the dry period of 1928 through 1934 is 66 taf and 134 taf long-term. The average annual for CVP north-of-Delta delivery in the dry period of 1928 through 1934 is 2077 taf and 2211 taf long-term. The average annual CVP south-of-Delta delivery in the dry period of 1928 through 1934 is 1678 taf and 2482 taf long-term. The average annual CVP south-of-Delta agricultural delivery in the dry period of 1928 through 1934 is 345 taf and 1011 taf long-term.

Table II.1.2. Percent Allocation Summary

	Water Year Type	SWP NOD		SWP SOD			CVP NOD				CVP SOD			
Water Year	**Sac 40-30-30 Index**	FRSA	MI	MWD	AG	Other MI	AG	SC	MI	RF	AG	MI	EX	RF
1922	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	87%	100%	100%	100%
1923	**BN**	100%	100%	100%	100%	100%	80%	100%	100%	100%	62%	87%	100%	100%
1924	**C**	50%	24%	26%	25%	24%	2%	75%	52%	75%	2%	52%	75%	75%
1925	**D**	100%	37%	41%	38%	37%	47%	100%	75%	100%	47%	75%	100%	100%
1926	**D**	100%	74%	90%	75%	74%	23%	100%	73%	100%	23%	73%	100%	100%
1927	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	78%	100%	100%	100%
1928	**AN**	100%	80%	90%	82%	80%	73%	100%	98%	100%	73%	98%	100%	100%
1929	**C**	100%	25%	27%	26%	25%	3%	100%	53%	100%	3%	53%	100%	100%
1930	**D**	100%	69%	76%	69%	69%	28%	100%	75%	100%	28%	75%	100%	100%
1931	**C**	50%	28%	30%	28%	28%	1%	75%	51%	75%	1%	51%	75%	75%
1932	**D**	100%	39%	50%	40%	39%	6%	75%	56%	75%	6%	56%	75%	75%
1933	**C**	100%	41%	45%	41%	41%	3%	75%	53%	75%	3%	53%	75%	75%
1934	**C**	50%	42%	45%	42%	42%	20%	75%	70%	75%	20%	70%	75%	75%
1935	**BN**	100%	100%	100%	100%	100%	24%	100%	74%	100%	24%	74%	100%	100%
1936	**BN**	100%	100%	100%	100%	100%	52%	100%	77%	100%	52%	77%	100%	100%
1937	**BN**	100%	100%	100%	100%	100%	22%	100%	72%	100%	22%	72%	100%	100%
1938	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	68%	93%	100%	100%
1939	**D**	100%	89%	100%	90%	89%	64%	100%	89%	100%	64%	89%	100%	100%
1940	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	57%	82%	100%	100%
1941	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	74%	99%	100%	100%
1942	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	100%	100%	100%
1943	**W**	100%	92%	100%	98%	92%	91%	100%	100%	100%	77%	100%	100%	100%
1944	**D**	100%	100%	100%	100%	100%	55%	100%	80%	100%	55%	80%	100%	100%
1945	**BN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	82%	100%	100%	100%
1946	**BN**	100%	100%	100%	100%	100%	94%	100%	100%	100%	69%	94%	100%	100%
1947	**D**	100%	69%	75%	69%	69%	68%	100%	93%	100%	66%	91%	100%	100%
1948	**BN**	100%	75%	82%	75%	75%	84%	100%	100%	100%	56%	81%	100%	100%
1949	**D**	100%	67%	76%	67%	67%	71%	100%	96%	100%	66%	91%	100%	100%
1950	**BN**	100%	76%	90%	76%	76%	37%	100%	75%	100%	37%	75%	100%	100%
1951	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	74%	99%	100%	100%
1952	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	82%	100%	100%	100%
1953	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%
1954	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	81%	100%	100%	100%
1955	**D**	100%	41%	50%	42%	41%	54%	100%	79%	100%	54%	79%	100%	100%
1956	**C**	100%	100%	100%	100%	100%	100%	100%	100%	100%	88%	100%	100%	100%
1957	**AN**	100%	81%	98%	82%	81%	100%	100%	100%	100%	72%	97%	100%	100%
1958	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	82%	100%	100%	100%
1959	**BN**	100%	84%	87%	86%	84%	100%	100%	100%	100%	76%	100%	100%	100%
1960	**D**	100%	47%	47%	47%	47%	21%	100%	71%	100%	21%	71%	100%	100%
1961	**D**	100%	74%	74%	74%	74%	65%	100%	90%	100%	61%	86%	100%	100%
1962	**BN**	100%	85%	100%	86%	85%	85%	100%	100%	100%	67%	92%	100%	100%
1963	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	77%	100%	100%	100%
1964	**D**	100%	79%	88%	80%	79%	50%	100%	75%	100%	50%	75%	100%	100%
1965	**W**	100%	83%	100%	85%	83%	97%	100%	100%	100%	91%	100%	100%	100%
1966	**BN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	74%	99%	100%	100%
1967	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	78%	100%	100%	100%
1968	**BN**	100%	87%	100%	88%	87%	100%	100%	100%	100%	84%	100%	100%	100%
1969	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	82%	100%	100%	100%
1970	**W**	100%	100%	100%	100%	100%	84%	100%	100%	100%	72%	97%	100%	100%
1971	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	83%	100%	100%	100%
1972	**BN**	100%	73%	77%	75%	73%	70%	100%	95%	100%	67%	92%	100%	100%
1973	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	100%	100%	100%
1974	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%
1975	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	100%	100%	100%
1976	**C**	100%	75%	79%	76%	75%	18%	100%	68%	100%	18%	68%	100%	100%
1977	**C**	50%	19%	21%	20%	19%	0%	75%	50%	75%	0%	50%	75%	75%
1978	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	78%	100%	100%	100%
1979	**BN**	100%	100%	100%	100%	100%	94%	100%	100%	100%	83%	100%	100%	100%
1980	**AN**	100%	100%	100%	100%	100%	99%	100%	100%	100%	78%	100%	100%	100%
1981	**D**	100%	87%	100%	88%	87%	100%	100%	100%	100%	74%	99%	100%	100%
1982	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	79%	100%	100%	100%
1983	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	78%	100%	100%	100%
1984	**W**	100%	100%	100%	100%	100%	100%	100%	100%	100%	77%	100%	100%	100%
1985	**D**	100%	93%	100%	93%	93%	97%	100%	100%	100%	67%	92%	100%	100%
1986	**W**	100%	79%	100%	100%	79%	49%	100%	75%	100%	49%	75%	100%	100%
1987	**D**	100%	72%	80%	73%	72%	51%	100%	76%	100%	51%	76%	100%	100%
1988	**C**	50%	23%	24%	24%	23%	6%	100%	56%	100%	6%	56%	100%	100%
1989	**D**	100%	78%	79%	77%	78%	43%	100%	75%	100%	43%	75%	100%	100%
1990	**C**	100%	27%	29%	27%	27%	0%	100%	50%	100%	0%	50%	100%	100%
1991	**C**	50%	22%	24%	22%	22%	12%	75%	62%	75%	12%	62%	75%	75%
1992	**C**	100%	30%	34%	30%	30%	0%	100%	50%	100%	0%	50%	100%	100%
1993	**AN**	100%	100%	100%	100%	100%	100%	100%	100%	100%	74%	99%	100%	100%
1994	**C**	100%	77%	94%	77%	77%	100%	75%	100%	75%	88%	100%	75%	75%

Table II.1.2 shows the percent annual water year allocation for SWP and CVP. SWP north-of-Delta includes Feather River (FRSA) and municipal and industrial (MI) allocations. SWP south-of-Delta includes Metropolitan Water District (MWD), agriculture (AG) and other municipal and industrial (MI) allocations. CVP north-of-Delta includes agriculture (AG), Settlement Contractors (SC), municipal and industrial (MI) and refuge (RF) allocations. CVP south-of-Delta includes agriculture (AG), municipal and industrial (MI), exchange contractors (EX) and refuge (RF) allocations.

Figure II.1.1
Frequency of Total SWP south-of-Delta Deliveries Reliability

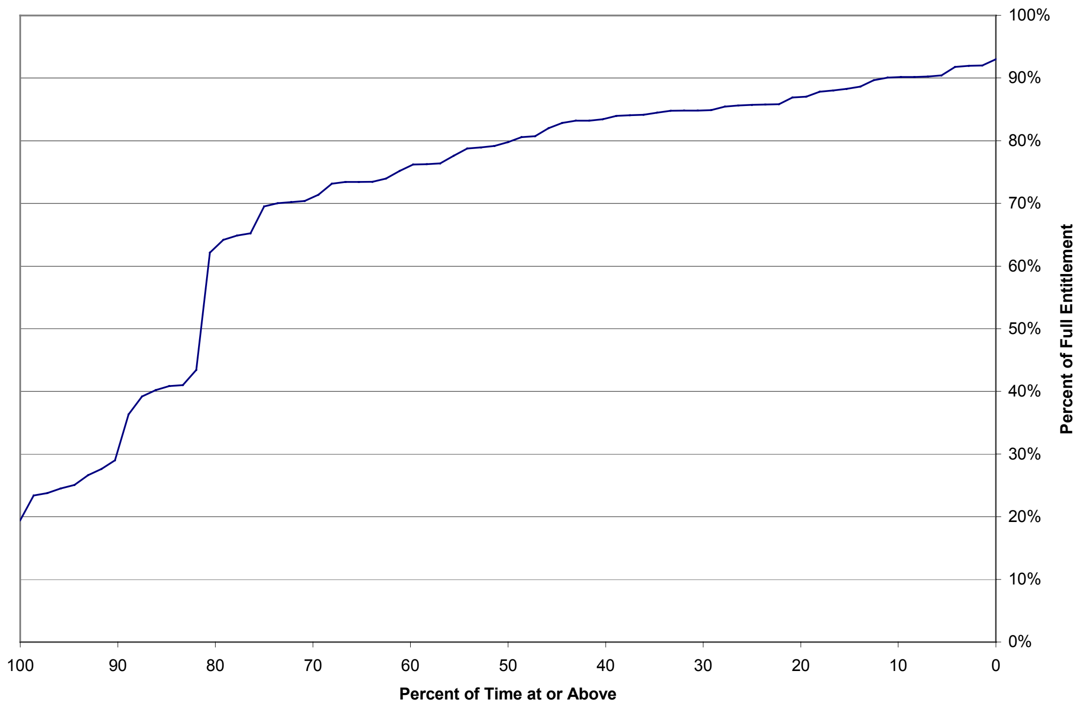

Figure II.1.1 shows the frequency of total annual SWP south-of-Delta full entitlement reliability. In 50 percent of the years, at least 80% of the SWP south-of-Delta full entitlement is met.

Figure II.1.2
Frequency of SWP Interruptble Delivery

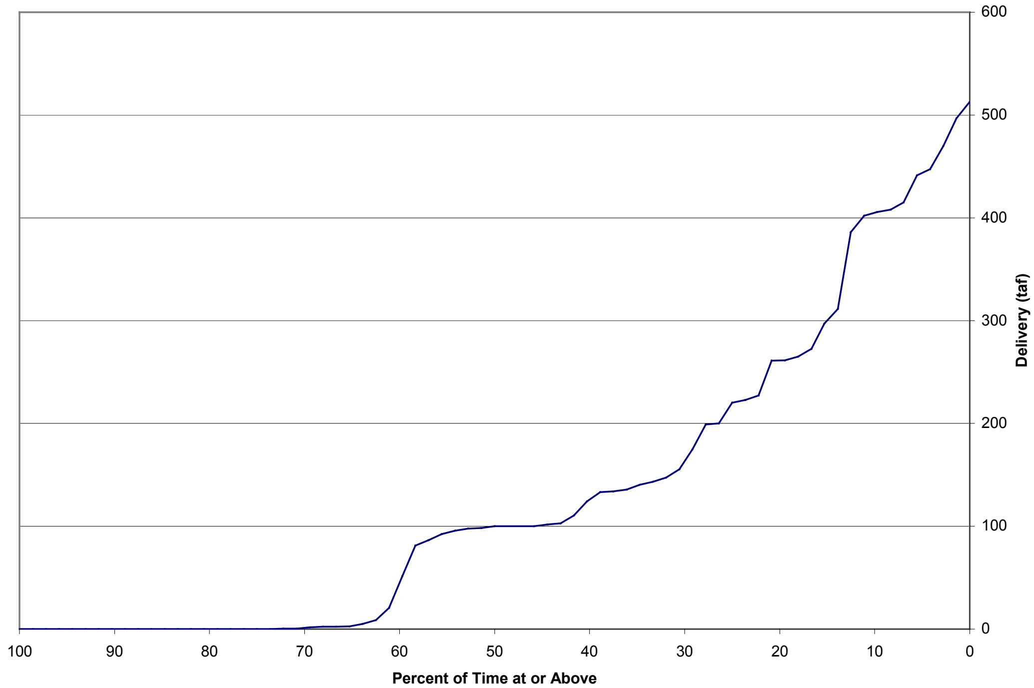

Figure II.1.2 shows the frequency of total annual SWP interruptible delivery. In about 50% of the years, the total annual interruptible delivery is at least 100 taf. The average annual interruptible delivery is 134 taf.

Figure II.1.3
Frequency of Total CVP SOD Delivery

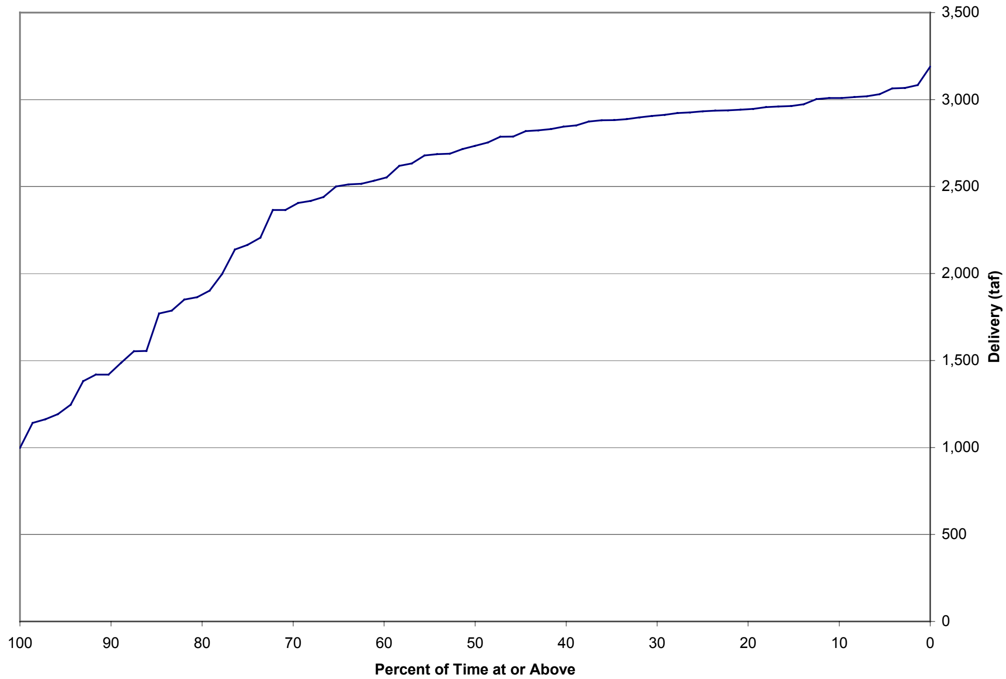

Figure II.1.3 shows the frequency of total annual CVP south-of-Delta delivery. In 50 percent of the years, the total annual CVP south-of-Delta delivery is at least 2,735 taf. The average annual CVP south-of-Delta delivery is 2,482 taf.

Figure II.1.4
Frequency of Total CVP SOD Ag Delivery

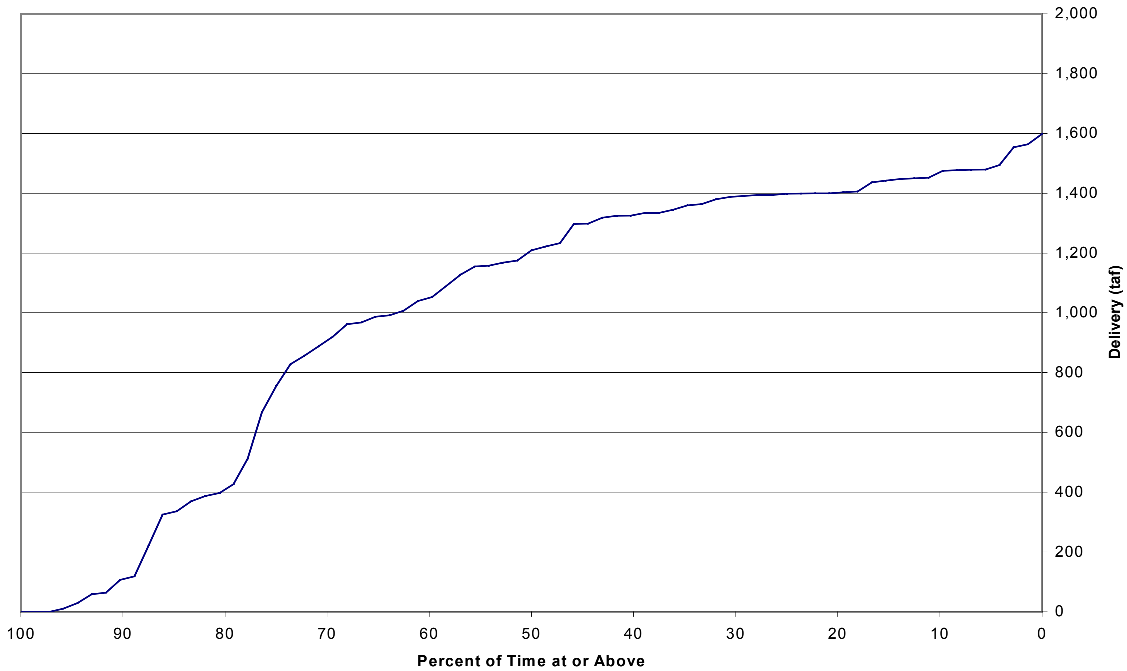

Figure II.1.4 shows the frequency of total CVP south-of-Delta delivery to agricultural contractors. In 50% of the years, the total annual CVP south-of-Delta delivery to agricultural contractors is at least 1,209 taf. The average annual CVP south-of-Delta delivery to agricultural contractors is 1,011 taf.

Figure II.1.5
Frequency of Total CVP NOD Delivery

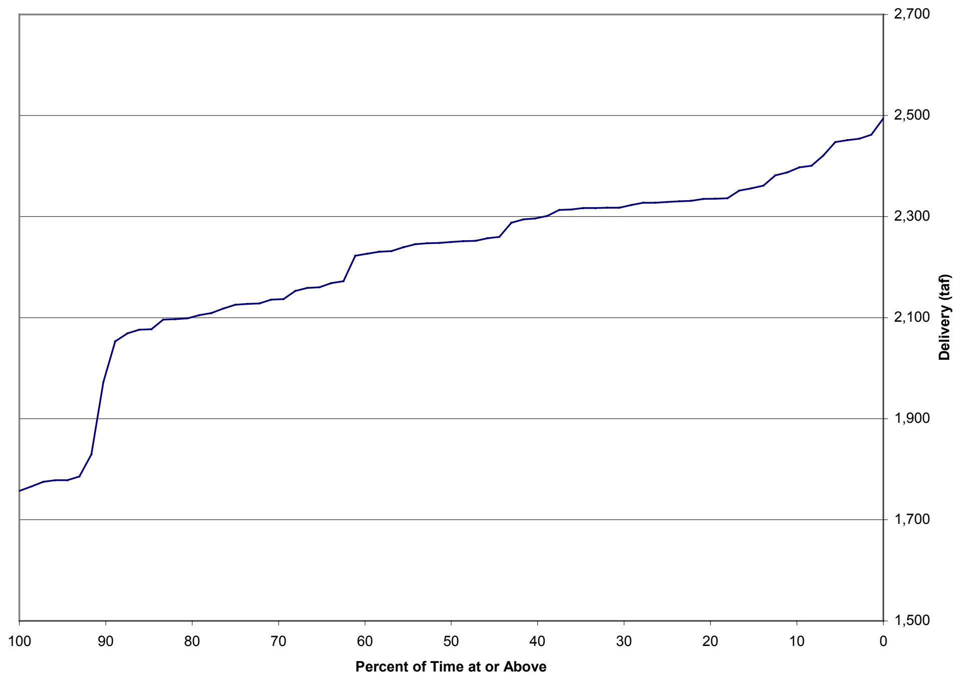

Figure II.1.5 shows the frequency of total CVP north-of-Delta delivery. In 50% of the years, the total annual CVP north-of-Delta delivery is at least 2,250 taf. The average annual CVP north-of-Delta delivery to agricultural contractors is 2,211 taf.

II.2. CVPIA (b)(2) Operations

Figure II.2.1
Total End of Year (b)(2) Costs

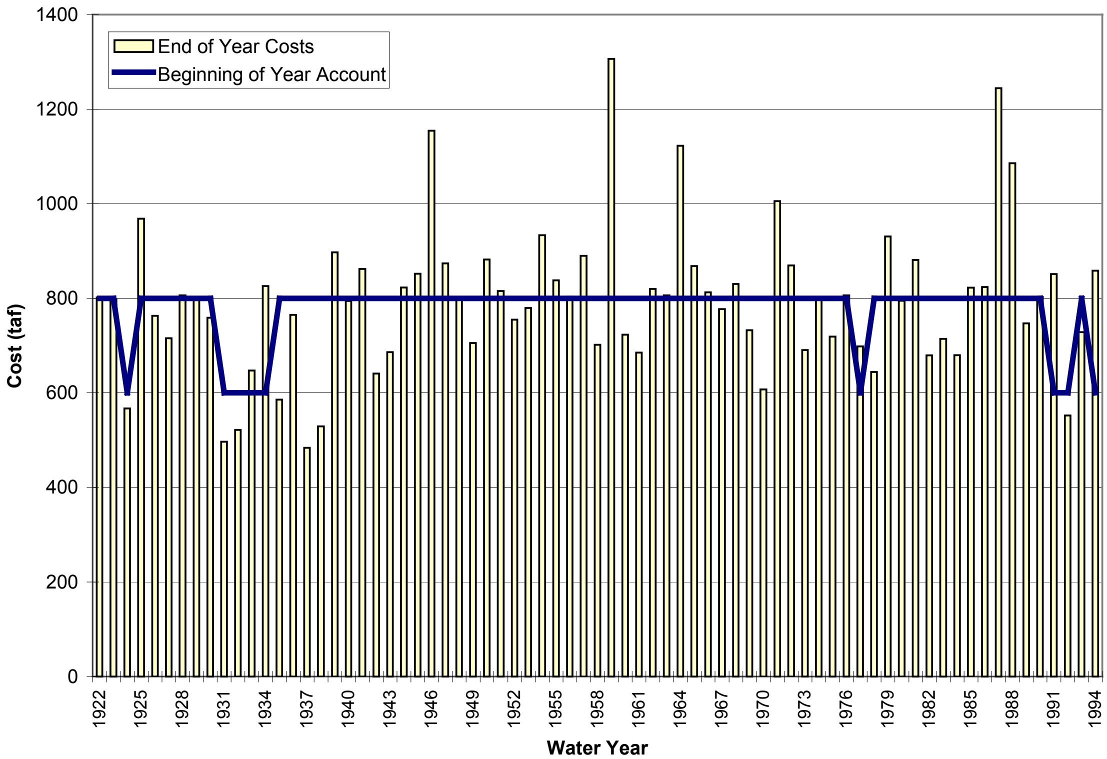

Figure II.2.1 shows the total end of year (b)(2) costs and the beginning of year (b)(2) account. The cost is computed from the (b)(2) study with D1485 as the baseline. The heavy line shows the total (b)(2) account limit at the beginning of each year (800 taf in normal years, 600 taf in Shasta critical years). The bars show the actual total end of year (b)(2) costs for each year. There are several years throughout the 73-year study period in which the total (b)(2) cost exceeded the (b)(2) account. This can happen for several reasons: 1. CVP costs, as measured through (b)(2) metrics, of satisfying WQCP standards exceed the allocated (b)(2) account. This is the primary cause for account over-expenditures. 2. CALSIM is a monthly time-step model and will impose a (b)(2) action as long as there is a balance in the (b)(2) account at the beginning of the month and reserve criteria are satisfied. When a (b)(2) action is imposed, it is imposed for the entire month, and the action taken resulted in a cost more than the remaining (b)(2) account balance.

There are also years when the total (b)(2) cost is less than the (b)(2) account limit as shown in the chart. In those years, all of the (b)(2) actions are taken, but the total cost of those actions is less than 800 taf or 600 taf (b)(2) account.

Figure II.2.2
Total Annual WQCP Cost

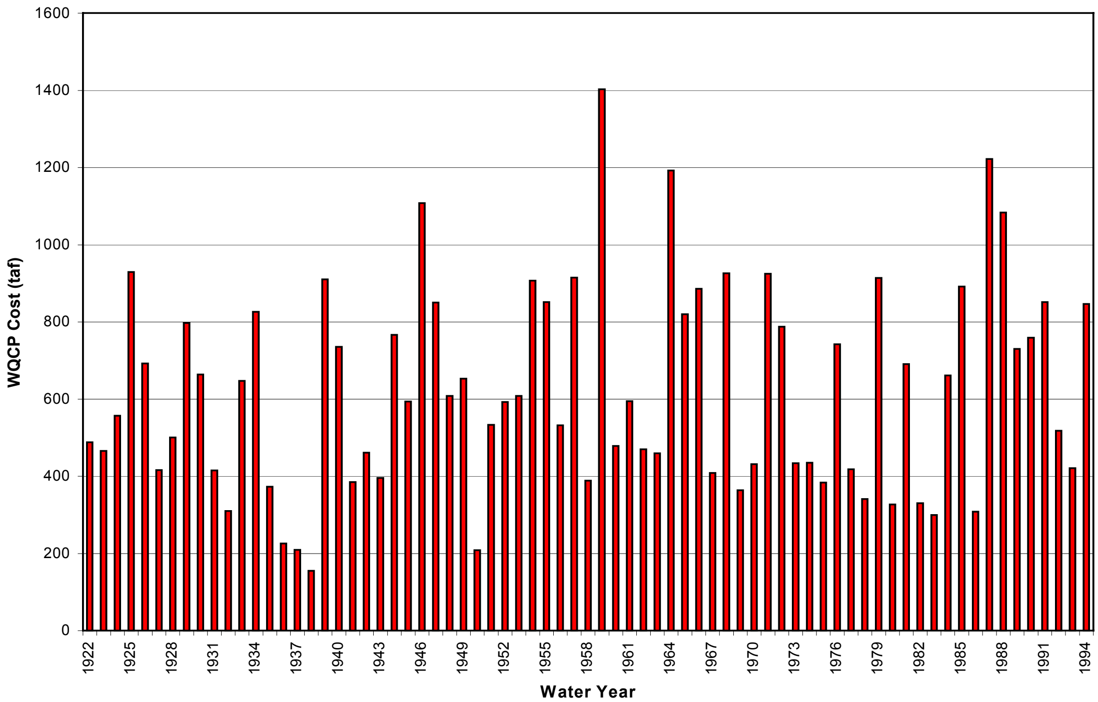

Figure II.2.2 shows the total annual CVP WQCP costs. This is the total cost, as measured through (b)(2) accounting metrics, to the CVP due to regulatory requirements of the WQCP. The cost is computed in the (b)(2) study using the results of the WQCP and D1485 studies, with D1485 as the baseline.

Figure II.2.3
Percent of Time (b)(2) Actions Taken

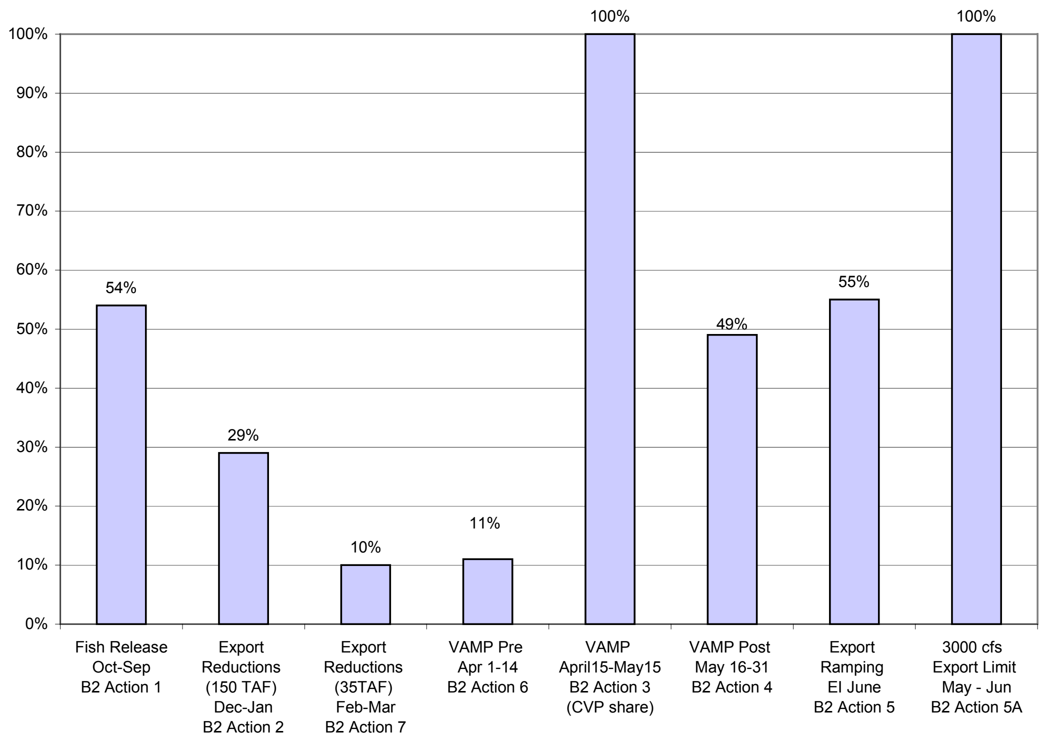

Figure II.2.3 shows the percent of time (b)(2) actions are taken during the 73-year study period. The (b)(2) actions are imposed on the CVP system only.

II.3. EWA Operations

Figure II.3.1
Percent of Time EWA Actions Taken

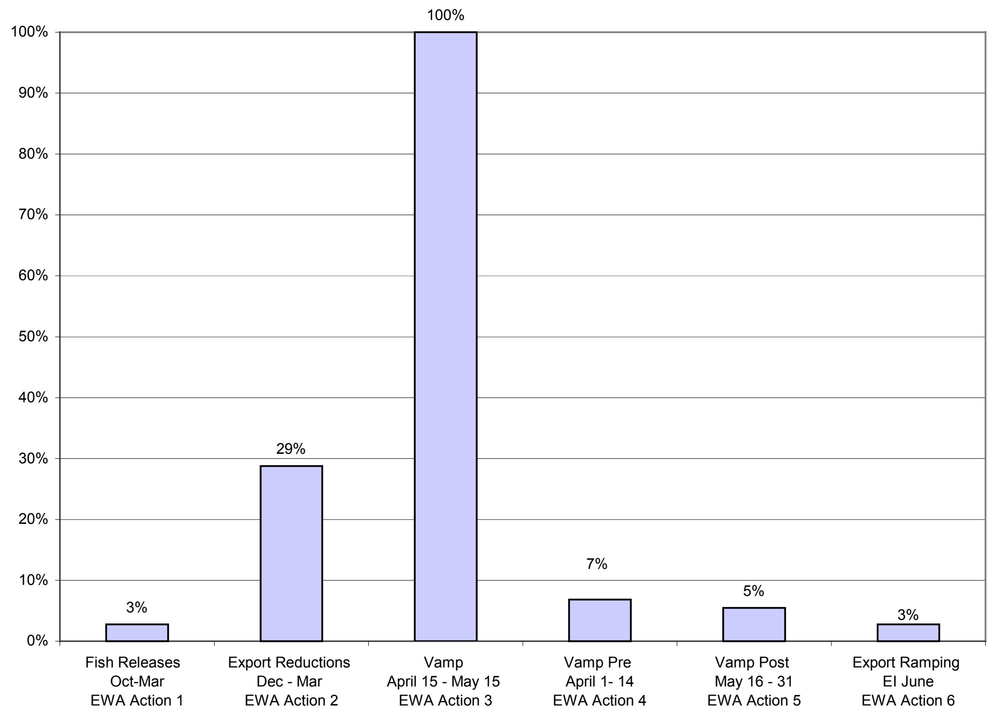

Figure II.3.1 shows the percent of time EWA actions are taken. While the (b)(2) actions are imposed only on the CVP system, EWA actions are imposed on both the SWP and CVP systems. Four of the EWA actions are the same as the (b)(2) actions. The EWA would impose actions only on the SWP if (b)(2) actions were imposed on the CVP. However, if (b)(2) actions were not imposed on the CVP because the (b)(2) account is exhausted, then the EWA will impose actions on both the CVP and SWP as long as the EWA has sufficient collateral to repay the debt to the projects.

Figure II.3.2
Percent of Times (b)(2) and EWA Actions Taken

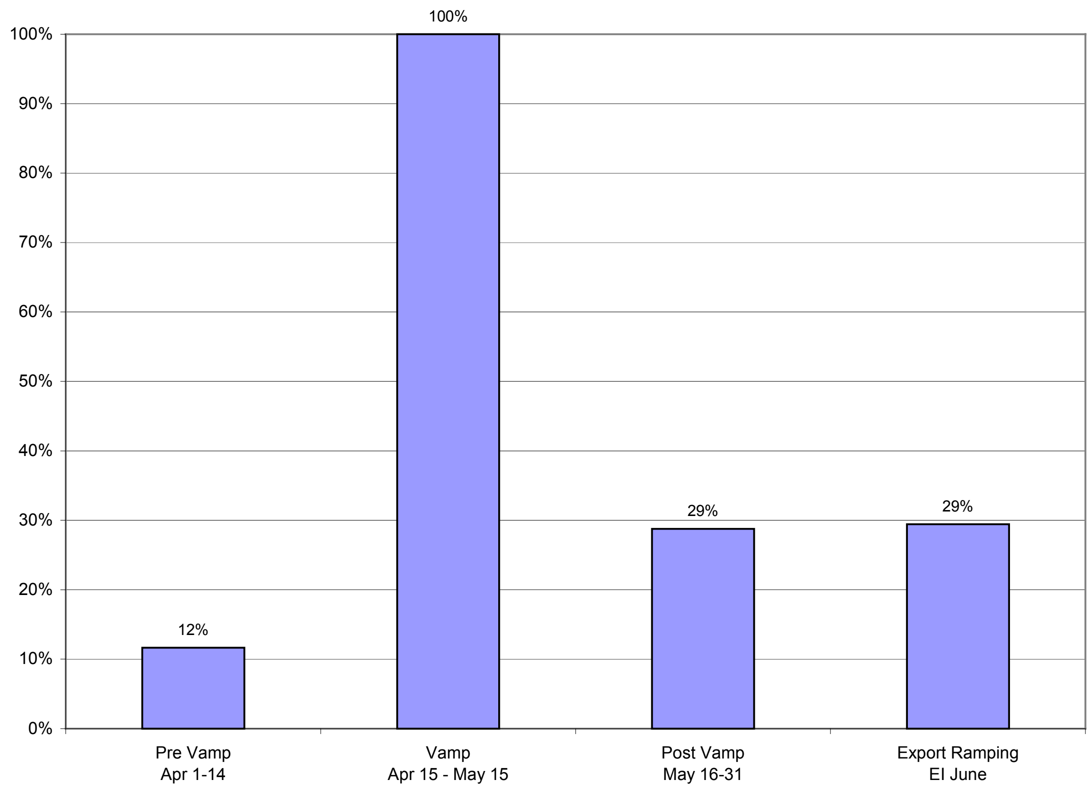

Figure II.3.2 shows the percent of time (b)(2) and EWA actions are taken. The actions are common to (b)(2) and EWA. These are percent of times when:

- (b)(2) actions are taken on the CVP, and EWA actions are taken on the SWP (this qualifies as one full action taken)
- no (b)(2) action is taken on the CVP, but EWA actions are taken on both the SWP and CVP (this qualifies as one full action taken)
- or (b)(2) actions are taken on the CVP, and EWA does not take actions (this qualifies as one half action taken)

Figure II.3.3
Frequency of Joint Point Use for EWA
(Includes 500 cfs July through September)

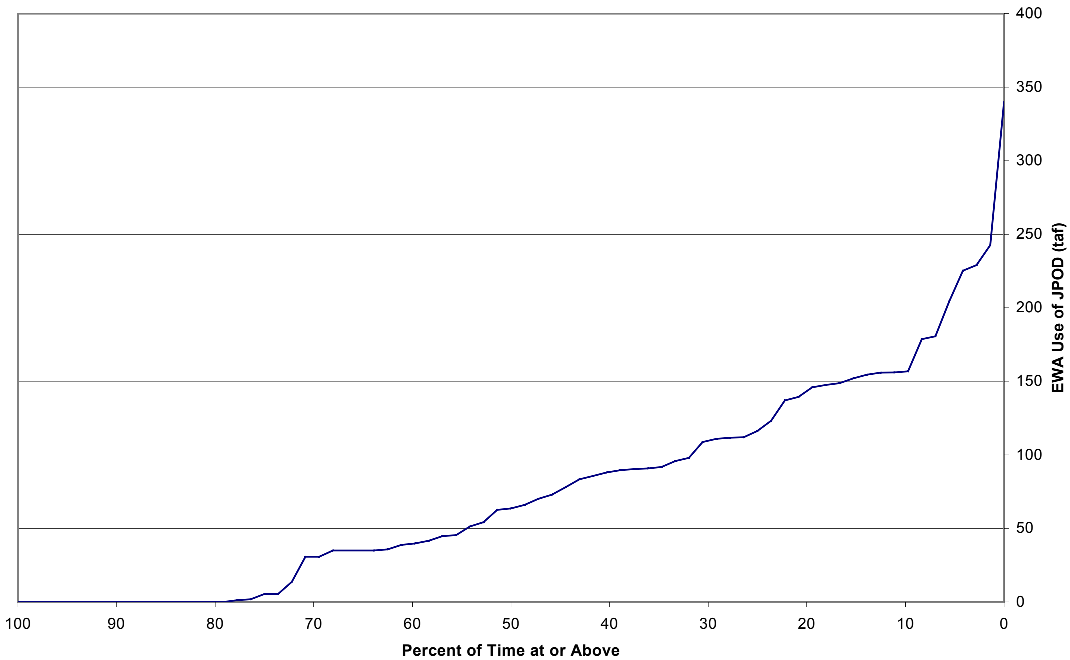

Figure II.3.3 shows the frequency of total annual use of joint-point-of-diversion for the EWA. This represents the total use of joint-point-of-diversion at Banks Pumping Plant to export water for the EWA, including a north-of-Delta purchase, EWA water stored in north-of-Delta project reservoirs, and surplus water. The average annual total use of joint-point-of-diversion for the EWA is 77 taf.

Figure II.3.4
EWA Use of JPOD and Dedicated 500 cfs Banks Capacity to Transfer NOD Purchase

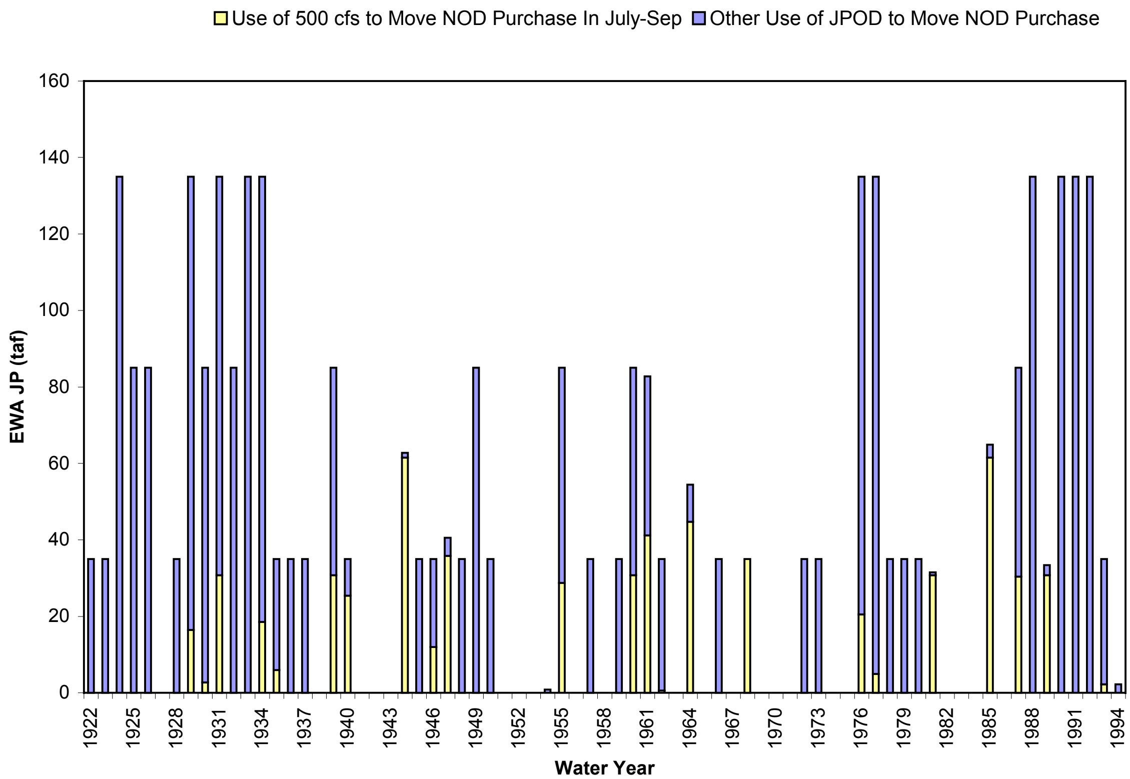

Figure II.3.4 shows the use of JPOD and dedicated 500 cfs to transfer the north-of-Delta EWA purchase. EWA north of Delta purchased water is moved through Banks Pumping Plant during Jul-Sep at the earliest possible opportunity. The purchased water is transferred through the EWA dedicated additional 500 cfs capacity at Banks in July through September if existing JPOD capacity is limiting. Average annual EWA usage of the additional 500 cfs Banks capacity is 8 taf.

Figure II.3.5
EWA Use of JPOD and Dedicated 500 cfs Banks Capacity toTransfer NOD Storage and Delta Surplus

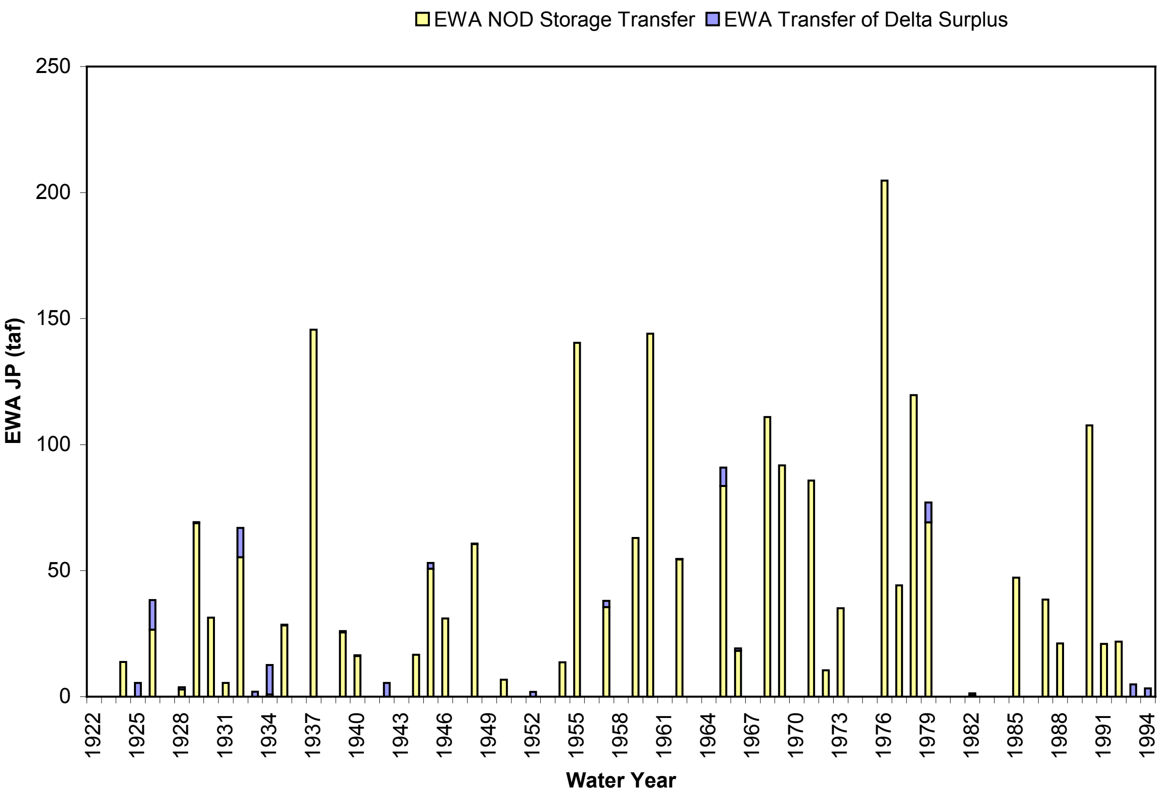

Figure II.3.5 shows total annual transfer of EWA water from north-of-Delta EWA storage and Delta Surplus into San Luis Reservoir through the use of joint-point-of-diversion and dedicated 500 cfs capacity through Banks Pumping Plant. When the EWA takes an action to reduce exports, the amount of storage backed up in Lake Oroville, Shasta Lake, or Folsom Lake as a result of EWA imposed export reduction is credited to the EWA account in those reservoirs. The transfer of EWA water from the northern reservoirs is prevalent in dry years because

- EWA storage in northern reservoirs is usually higher in dry years where EWA is less likely to lose its storage account due to flood control spills.
- There is sufficient joint-point-of-diversion capacity available at Banks Pumping Plant to transfer EWA water in dry years

EWA NOD stored water, when available, is moved to EWA SOD storage when EWA has capacity at Banks – first with the 50% of JPOD capacity and then using the 500 cfs additional Banks capacity (July-Sept) if not used by north-of-Delta purchase. This typically occurs during Jun-Aug, but can occur in any month.

The average annual transfer of EWA water from north-of-Delta reservoirs to San Luis reservoir is 30 taf.

Figure II.3.6
EWA Assets Utilized

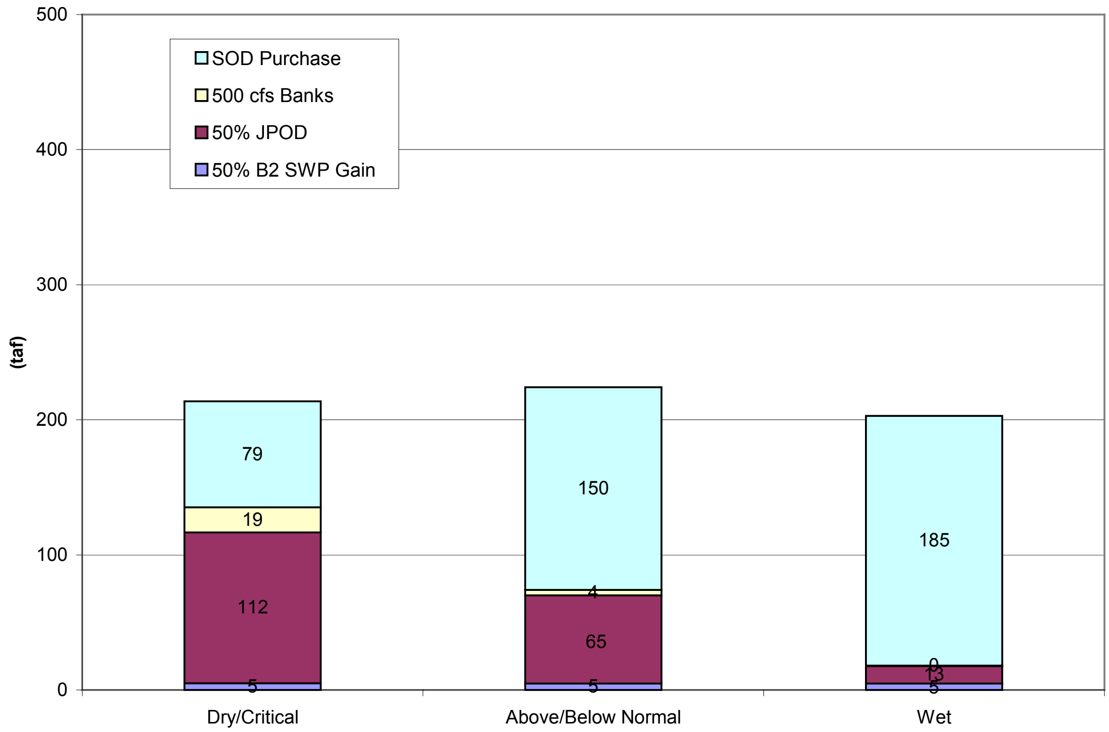

Figure II.3.6 shows EWA assets utilized by water-year type. The assets shown include south-of-Delta purchase, 500 cfs additional Banks Pumping Plant capacity, the remainder of the 50% of joint-point-of-diversion capability, and 50% of (b)(2) SWP gain. The average asset from south-of-Delta purchase is 79 taf/year in dry and critical years, 150 taf/year in above and below normal years, and 185 taf/year in wet years. The average asset from 500 cfs additional Banks Pumping Plant capacity is 19 taf/year in dry and critical years, 4 taf/year in above and below normal years, and 0 taf/year in wet years. The average remaining asset from 50% of joint point of diversion capability is 112 taf/year in dry and critical years, 65 taf/year in above and below normal years, and 13 taf/year in wet years. The average asset from 50% of (b)(2) SWP gain is 5 taf/year in dry and critical years, 5 taf/year in above and below normal years, and 5 taf/year in wet years. These are the major assets that the EWA utilizes to accumulate collateral south-of-Delta so that it can repay debt to the projects when it imposes an EWA action.

Figure II.3.7
SOD EWA Unpaid Debt

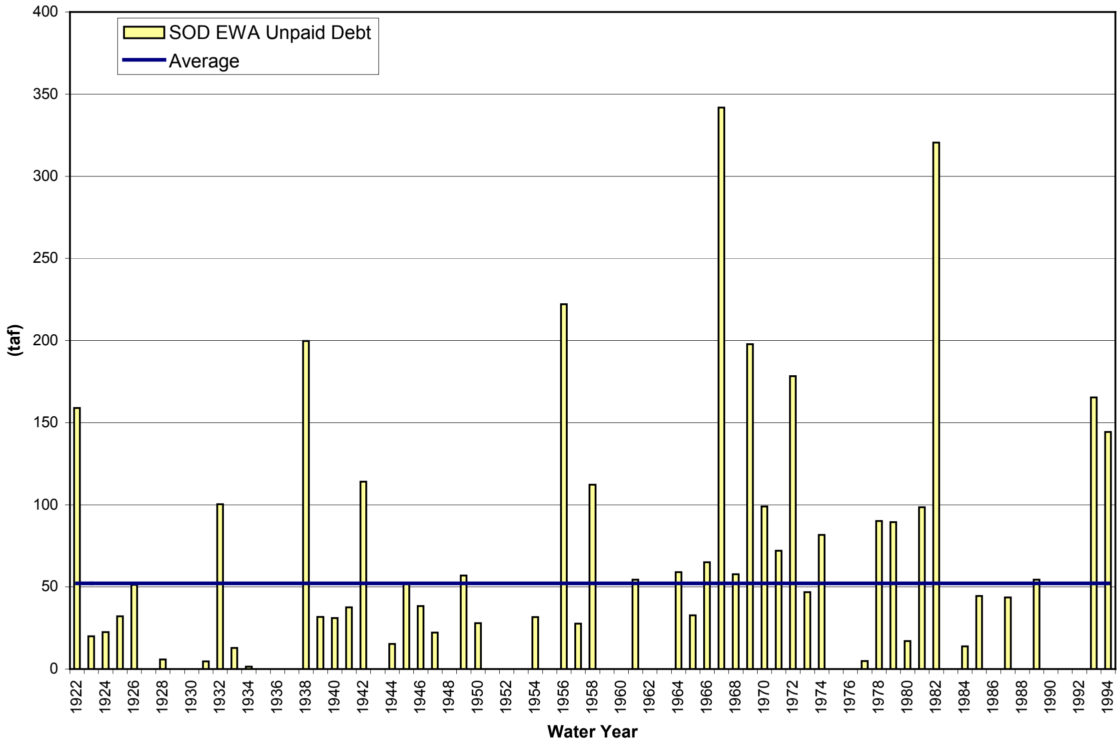

Figure II.3.7 shows the south of Delta EWA unpaid debts for each water year. The south of Delta EWA unpaid debt ranges from 0 to 342 taf. The average south of Delta EWA unpaid debt is 52 taf/year.

Figure II.3.8
EWA north-of-Delta and south-of-Delta Purchase

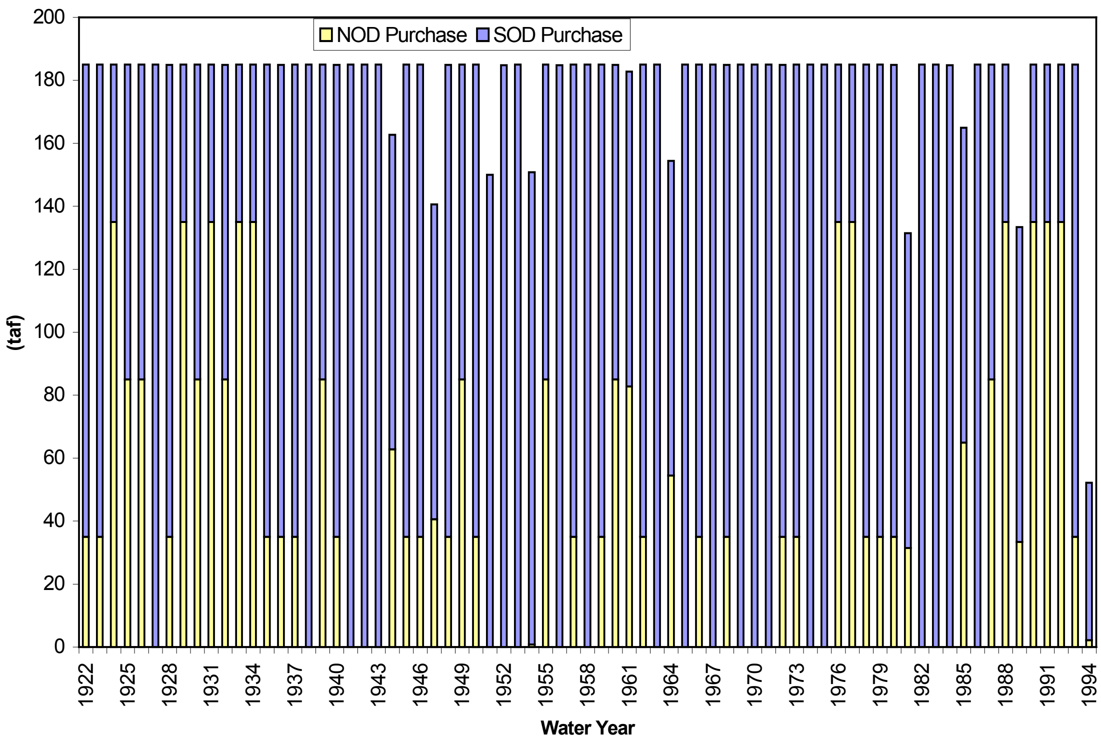

Figure II.3.8 shows EWA south-of-Delta and north-of-Delta purchase. The south-of-Delta purchase amounts are 50 taf/year in critical years, 100 taf/year in dry years, 150 taf/year in above and below normal years, and 185 taf/year in wet years. The north-of-Delta purchase amounts are 135 taf/year in critical years, 85 taf/year in dry years, 35 taf/year in above and below normal years, and 0 taf/year in wet years. The EWA uses the purchase water to repay debts to the projects.

Figure II.3.9
EWA Storage in San Luis Reservoir

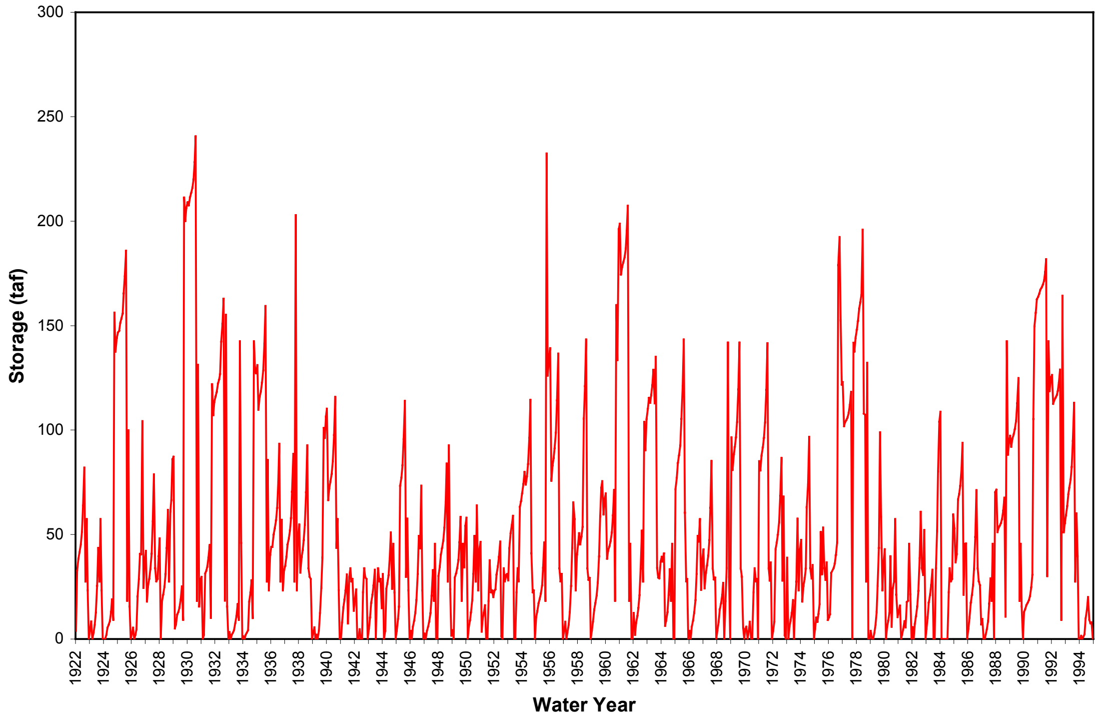

Figure II.3.9 shows EWA San Luis storage. This is EWA's storage account in San Luis Reservoir. This is a part of the south-of-Delta EWA collateral that the EWA accumulates from the various assets. The collateral is used to repay EWA debts to the projects when EWA incurs a debt on the projects by taking an EWA action. EWA will lose its storage in San Luis reservoir if storage is filled. EWA storage is usually high in dry years because:

- During dry years, EWA actions do not cost as much water because baseline deliveries are low. Therefore, EWA does not have much debt to repay to the projects.
- San Luis reservoir has storage capacity available for EWA to store its water. EWA San Luis reservoir does not spill for several consecutive years.
- In dry years, EWA has more opportunity to back up water in Lake Oroville, Shasta Lake, and Folsom Lake because there is less chance of losing that water due to flood control spills from the reservoirs.
- There is sufficient joint-point-of-diversion capacity available at Banks Pumping Plant.

Figure II.3.10
NOD SWP EWA Unpaid debt

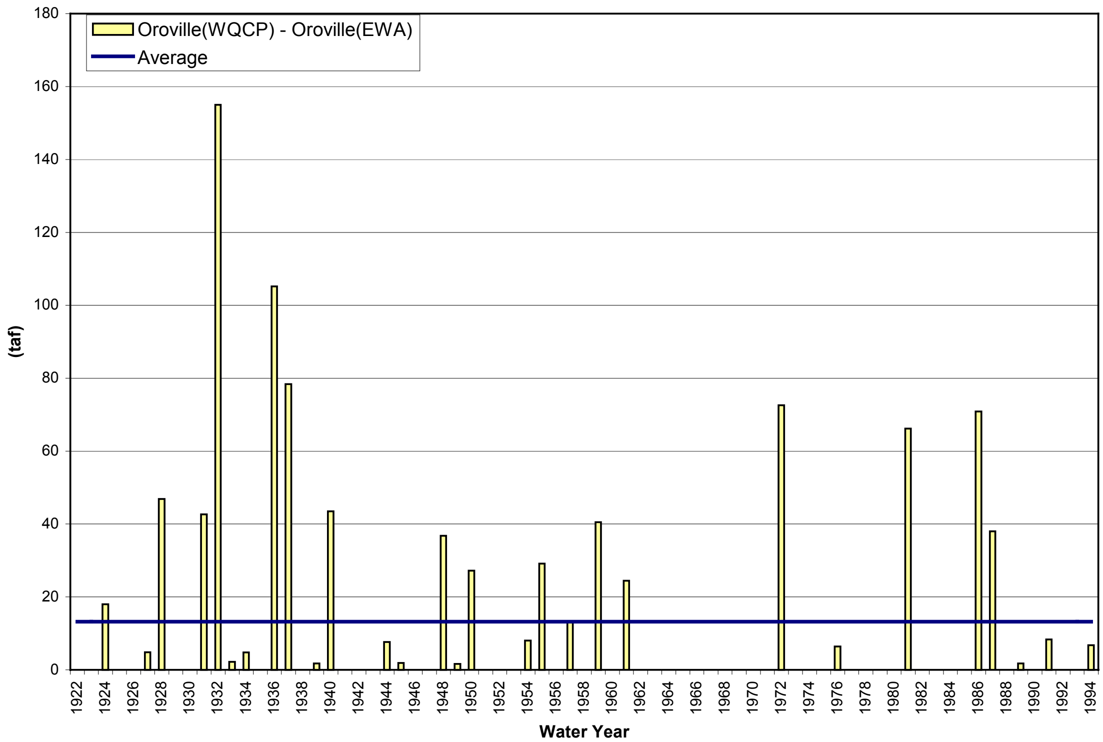

Figure II.3.10 shows the north of Delta SWP EWA unpaid debts for each water year. This debt is calculated as the storage difference at Oroville Reservoir in the EWA versus WQCP run for each water year. The north of Delta SWP EWA unpaid debt ranges from 0 to 155 taf. The average north of Delta SWP EWA unpaid debt is 13 taf/year. This debt is paid to Oroville as SWP add-water. Much of this debt may come from flood release water lost due to export curtailments. This loss leads to a lower San Luis level in the EWA versus the WQCP run and thus more water to be pulled out of Oroville Reservoir in the EWA run to meet rule curve. Also the 100% activation of VAMP may contribute to the NOD SWP EWA unpaid debt. Further review of north of Delta EWA unpaid debt may be needed.

Figure II.3.11
NOD CVP EWA Unpaid Debt

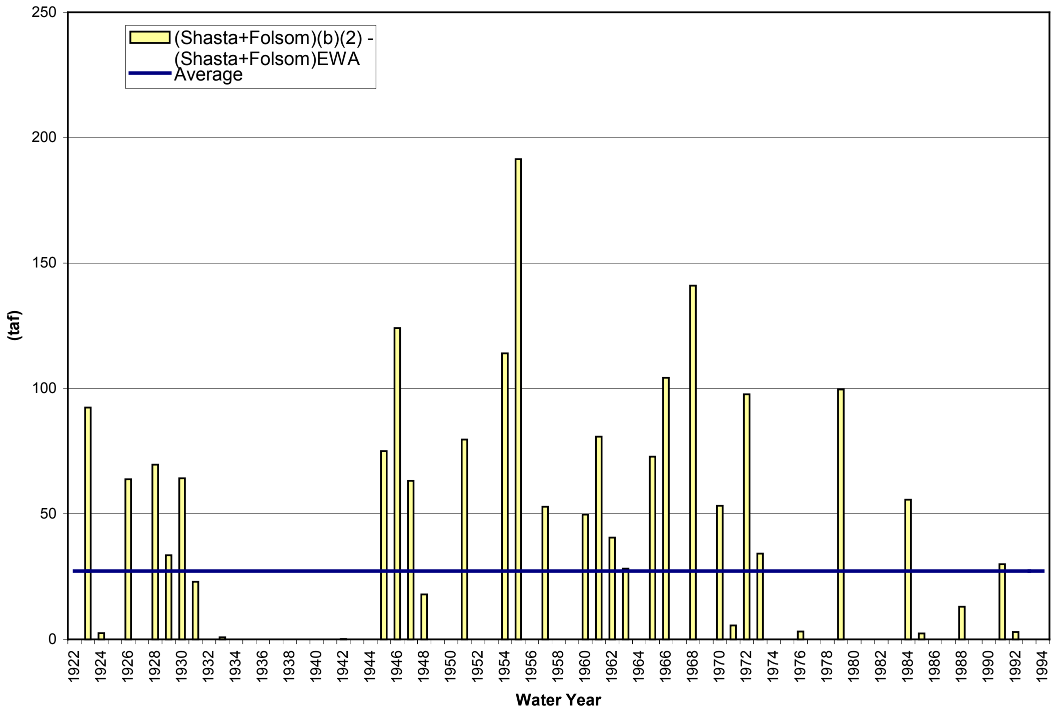

Figure II.3.11 shows the north of Delta CVP EWA unpaid debts for each water year. This debt is calculated as the storage difference at Shasta and Folsom Lakes in the EWA versus (b)(2) run for each water year. The north of Delta CVP EWA unpaid debt ranges from 0 to 191 taf. The average north of Delta CVP EWA unpaid debt is 27 taf/year.

II.4. Trinity River

Figure II.4.1
Trinity Lake Storage

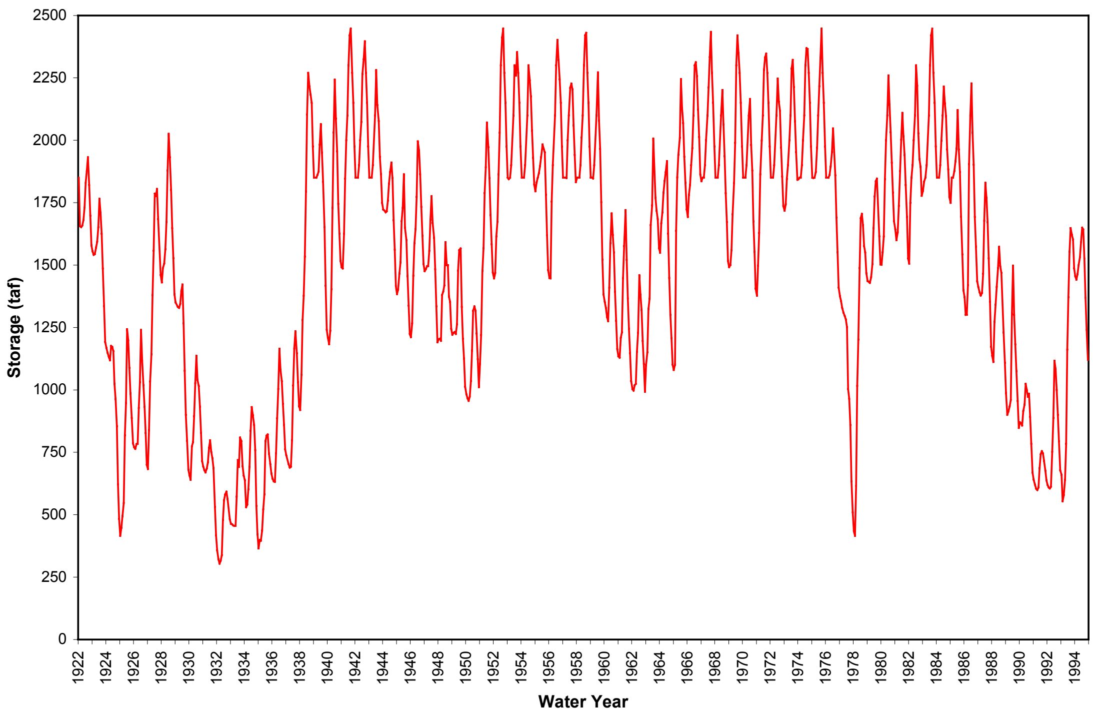

Figure II.4.1 shows Trinity Lake storage. The reservoir is operated to meet the Trinity River minimum required flow and export of water to the Sacramento River system.

Figure II.4.2
Total Annual Trinity River Minimum Instream Flow

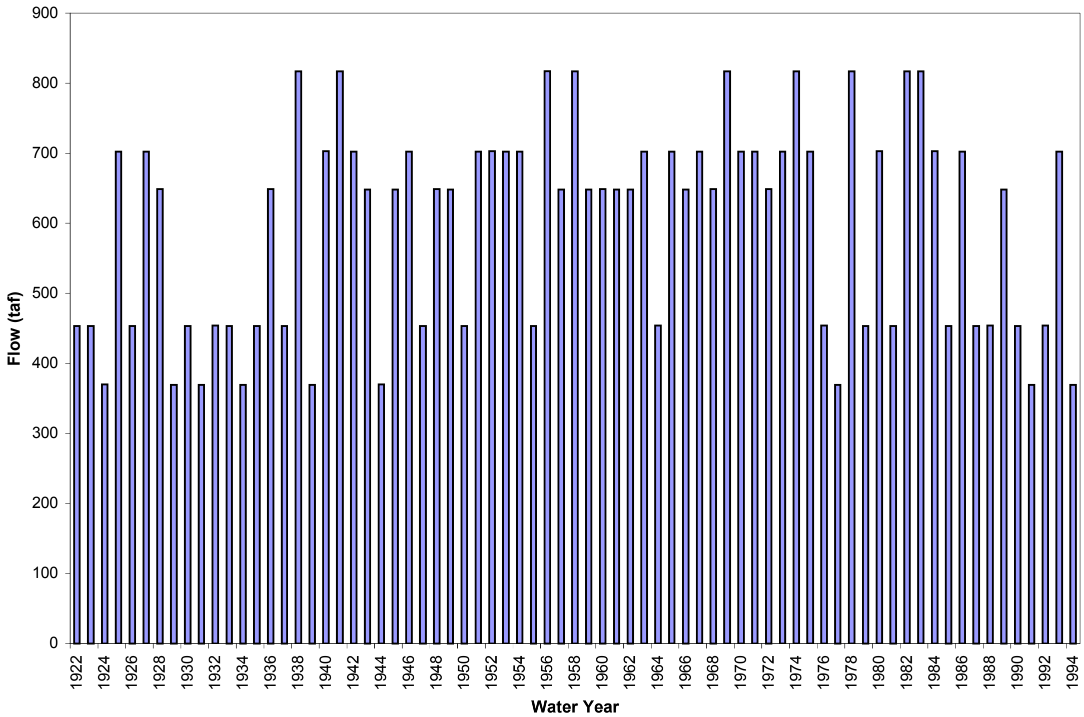

Figure II.4.2 shows the total annual Trinity River minimum instream flow for all years. The flows varied from 369 taf/year in dry years to 817 taf/year in wet years, based on the Trinity River index.

Figure II.4.3
Total Annual Trinity River Export

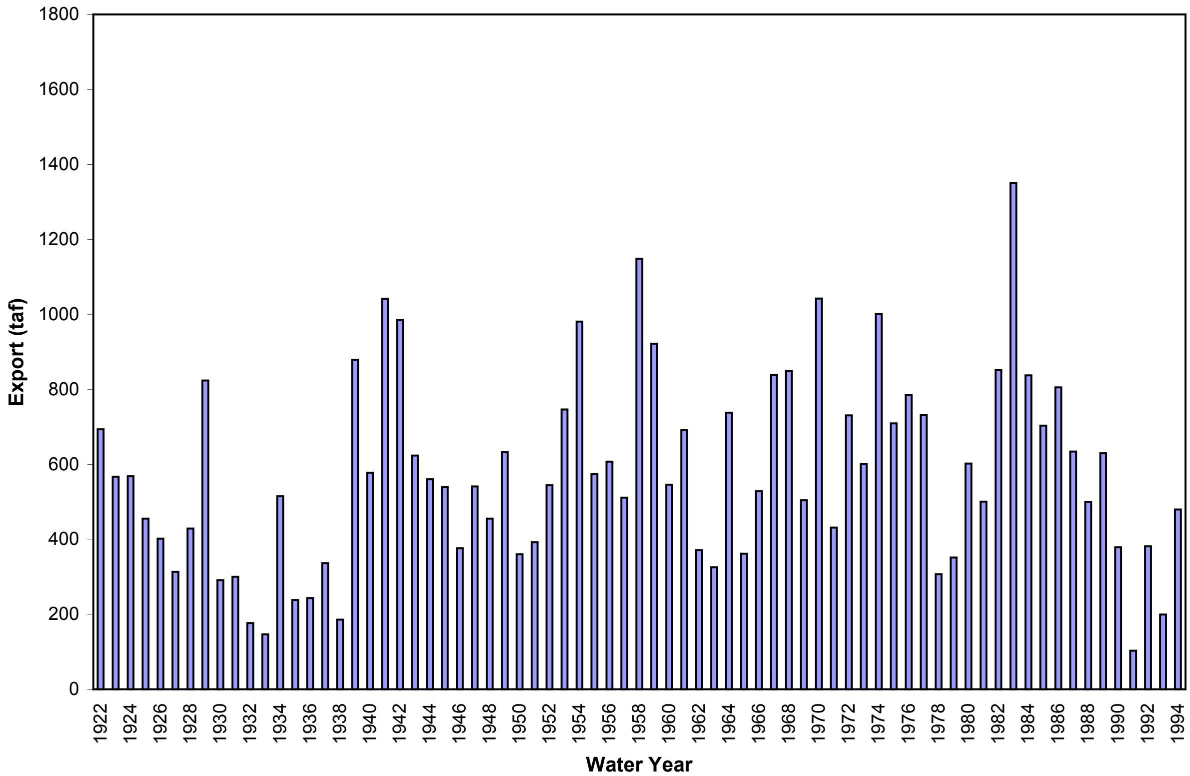

Figure II.4.3 shows the total Trinity River water exported annually to the Sacramento River system. The average annual export is 576 taf.

II.5. Sacramento River

Figure II.5.1
Shasta Lake Storage

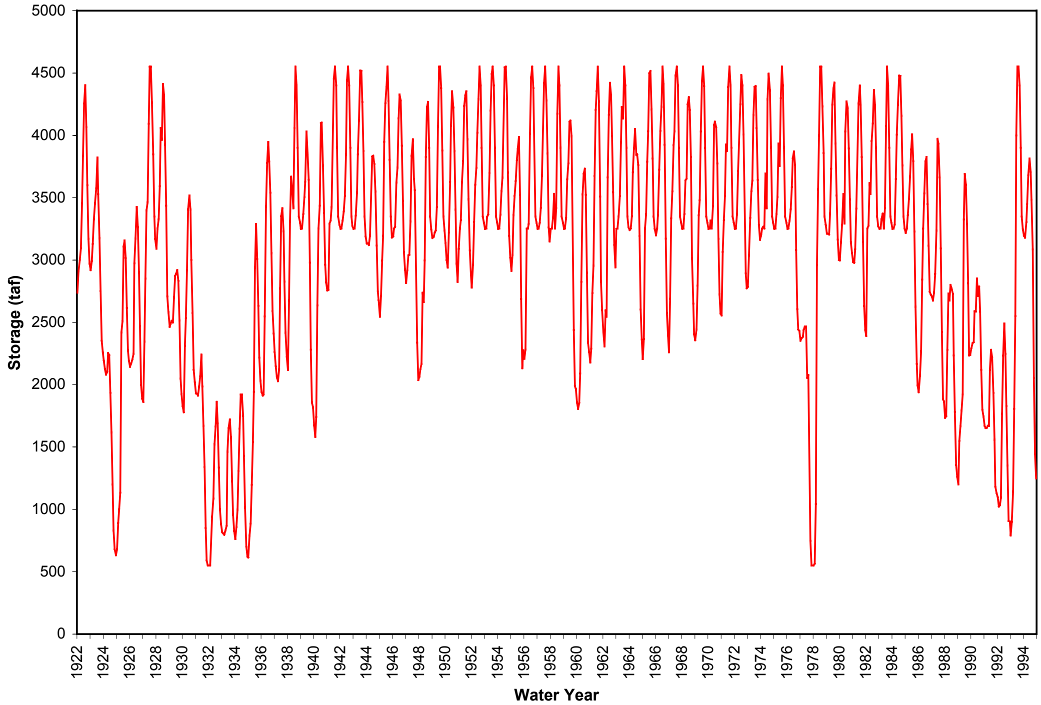

Figure II.5.1 shows Shasta Lake storage. There are 14 years in which the Shasta Lake carryover storage is lower than 1.9 maf. In 7 of those years, the carryover storage is between 1,000 and 1,900 taf, and in 7 of those years, the carryover storage is between 550 and 1000 taf. Most of the low carryover storage occurs in dry years including 1924, the 1928 through 1934 dry period, 1977, and the 1986 through 1992 dry period. In those dry years, Shasta reservoir is operated mostly to meet fish releases or temperature control flows at Keswick Dam or navigational control flow requirements. The CVP Settlement Contractors (full allocation 2.2 maf/year) are assumed to use their entire yearly allocation, whether full or 25% deficiency. This is a conservative approach that aggravates the low Shasta carryover problem in this simulation. While it is likely that NMFS and Reclamation would develop extraordinary measures to avoid carryover as low as is shown here in dry years, it is not possible to simulate this adaptive management approach with this version of CALSIM.

Table II.5.1
Shasta Lake Release Control

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Carryover Storage, taf
1922	NCP	NCP	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	NCP	NCP	2972
1923	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	NCP	NCP	Keswick	2259
1924	NCP	NCP	Keswick	Keswick	Keswick	Other	NCP	NCP	Other	Other	NCP	NCP	633
1925	Keswick	Keswick	Keswick	Keswick	Keswick	Other	Keswick	Keswick	NCP	NCP	NCP	Keswick	2191
1926	Keswick	NCP	Keswick	Keswick	Keswick	Other	Keswick	NCP	NCP	Other	Other	NCP	1888
1927	Keswick	Keswick	Keswick	Keswick	Other	Keswick	Other	Other	NCP	NCP	Other	NCP	3170
1928	Keswick	Other	Keswick	Keswick	Keswick	Other	Keswick	Keswick	NCP	Other	Other	NCP	2582
1929	NCP	Keswick	Keswick	Other	Keswick	Other	Other	NCP	NCP	Other	Other	NCP	1924
1930	NCP	Other	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	Other	Keswick	2019
1931	Keswick	NCP	Keswick	Keswick	Keswick	Keswick	NCP	NCP	NCP	Other	NCP	NCP	550
1932	NCP	Keswick	Keswick	Keswick	Keswick	Other	NCP	NCP	NCP	Other	NCP	NCP	882
1933	NCP	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	NCP	NCP	NCP	NCP	826
1934	NCP	Keswick	Keswick	Keswick	Keswick	Other	NCP	NCP	Other	Other	Other	NCP	621
1935	Keswick	Keswick	Keswick	Keswick	Other	Keswick	Keswick	NCP	NCP	NCP	NCP	Keswick	2033
1936	Keswick	NCP	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	NCP	2412
1937	NCP	NCP	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	2222
1938	Keswick	Keswick	Other	Other	Other	Other	Other	Keswick	Other	Other	Other	Other	3300
1939	Other	Other	Other	Keswick	Keswick	Keswick	NCP	NCP	Other	Other	Other	Other	1817
1940	Other	Other	Keswick	Keswick	Other	Other	Keswick	Keswick	NCP	NCP	NCP	NCP	2820
1941	Keswick	NCP	Other	Other	Other	Other	Other	Other	Other	Other	Other	NCP	3284
1942	Other	Other	Other	Other	Other	Other	Keswick	Other	Other	Other	Other	NCP	3272
1943	Other	Other	Other	Other	Other	Other	Keswick	Keswick	NCP	NCP	Other	NCP	3188
1944	Keswick	NCP	Keswick	Keswick	Keswick	Keswick	NCP	Keswick	NCP	Other	NCP	NCP	2679
1945	Other	Keswick	Keswick	Keswick	Other	Keswick	Keswick	Keswick	Other	NCP	Other	NCP	3180
1946	Keswick	Other	Other	Other	Other	Keswick	NCP	NCP	NCP	NCP	NCP	NCP	2923
1947	NCP	NCP	Keswick	NCP	Keswick	Keswick	Keswick	NCP	NCP	Other	Other	Other	2037
1948	Keswick	Keswick	Keswick	Keswick	Other	Keswick	Keswick	Keswick	Keswick	Other	Other	Keswick	3245
1949	Keswick	NCP	Keswick	Keswick	Keswick	Other	Keswick	Other	NCP	Other	Other	Keswick	3237
1950	Other	Other	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	NCP	NCP	NCP	2826
1951	Keswick	Other	Other	Other	Other	Keswick	NCP	Keswick	NCP	NCP	NCP	Other	2881
1952	Other	Keswick	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	3300
1953	Other	Other	Other	Other	Keswick	Keswick	Keswick	Other	Other	Other	Other	Other	3300
1954	Other	Other	Other	Other	Other	Other	Other	Other	NCP	Other	Other	Other	3018
1955	Other	Other	Other	Keswick	Other	Keswick	Other	Keswick	Other	Other	Other	Keswick	2276
1956	Other	Keswick	Other	Other	Other	Keswick	Keswick	Other	Keswick	Other	Other	Other	3300
1957	Other	Other	NCP	Keswick	Other	Other	Keswick	Other	Other	Other	Other	Other	3150
1958	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	3300
1959	Other	Other	Keswick	Other	Other	Other	NCP	NCP	Other	Other	Other	Other	1965
1960	Other	Other	Other	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	Other	Other	Keswick	2262
1961	Other	Keswick	Keswick	Keswick	Keswick	Keswick	Other	Other	Other	Other	Other	Other	2598
1962	Other	Other	Keswick	Other	Keswick	Keswick	Keswick	NCP	NCP	NCP	Other	Other	2942
1963	Other	Other	Other	Keswick	Other	Other	Other	Keswick	Keswick	Other	Other	Keswick	3263
1964	Keswick	Other	Other	Other	Keswick	Keswick	Other	NCP	NCP	Other	Other	Other	2361
1965	Other	Keswick	Other	Other	Keswick	Other	Other	Keswick	Other	NCP	Other	NCP	3249
1966	Keswick	Other	Other	Other	Other	Other	Other	NCP	Other	Other	Other	Other	2394
1967	Other	Keswick	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	3300
1968	Other	Other	Other	Keswick	Other	Other	NCP	Keswick	Other	Other	Other	Other	2404
1969	Other	Keswick	Keswick	Other	Other	Other	Other	Other	NCP	Other	Other	Other	3300
1970	Other	Other	Other	Other	Other	Keswick	NCP	Keswick	NCP	Other	Other	Other	2571
1971	Other	Keswick	Other	Other	Keswick	Other	NCP	Other	Other	Other	Other	Other	3300
1972	Other	Other	Other	Other	Other	Other	NCP	NCP	NCP	Other	Other	Other	2774
1973	Keswick	Keswick	Keswick	Other	Other	Other	Keswick	Keswick	NCP	NCP	Other	Other	3162
1974	Keswick	Other	Other	Other	Other	Other	Other	Keswick	Keswick	Other	Other	Other	3300
1975	Other	Other	Keswick	Keswick	Other	Other	Keswick	Other	Other	Other	Other	Other	3300
1976	Other	Other	Keswick	Keswick	NCP	Keswick	NCP	Other	Other	Other	Keswick	Keswick	2431
1977	Other	Keswick	Keswick	Keswick	Other	Other	Other	Other	Other	Other	Other	Other	550
1978	Other	Other	Keswick	Other	Other	Other	Other	Other	NCP	NCP	Other	Keswick	3281
1979	NCP	NCP	Other	Keswick	Keswick	Other	Keswick	Keswick	Other	NCP	Other	Other	3002
1980	Keswick	Keswick	Keswick	Other	Other	Keswick	Keswick	Keswick	NCP	NCP	NCP	Keswick	3055
1981	Keswick	NCP	Keswick	Keswick	Keswick	Other	Keswick	NCP	NCP	Other	Other	Other	2436
1982	Other	Other	Other	Other	Other	Other	Other	Keswick	Keswick	Keswick	Other	Keswick	3270
1983	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	3300
1984	Other	Other	Other	Other	Other	Other	Keswick	NCP	NCP	NCP	Other	Other	3252
1985	Other	Other	Other	Keswick	Keswick	Keswick	Keswick	NCP	Other	Other	Other	Other	1995
1986	Other	Keswick	Keswick	Keswick	Other	Other	Keswick	NCP	NCP	NCP	NCP	Keswick	2723
1987	Keswick	NCP	NCP	Keswick	Keswick	Keswick	NCP	NCP	Other	Other	Other	Other	1866
1988	Other	Other	Keswick	Keswick	Other	Other	NCP	Keswick	Other	Other	Other	NCP	1260
1989	Other	Keswick	Keswick	Keswick	Keswick	Keswick	Keswick	NCP	NCP	Other	Other	Keswick	2238
1990	Keswick	Keswick	Keswick	Keswick	Other	Keswick	NCP	Keswick	Other	Other	Other	Other	1743
1991	Other	Other	Other	Keswick	Other	Keswick	Keswick	NCP	Other	NCP	Other	NCP	1130
1992	Keswick	Other	Other	Keswick	Keswick	Keswick	Keswick	NCP	Other	Other	Other	Other	903
1993	Other	Other	Keswick	Keswick	Keswick	Other	Other	Other	Other	Other	Other	Keswick	3246
1994	Keswick	NCP	Keswick	Keswick	Keswick	Other	NCP	NCP	Other	Other	Other	Other	1248

Table II.5.1 shows the factors controlling Shasta releases. In the May 1928 to October 1934 dry period, there are 30 months when Keswick (Fish releases or temperature flows), 32 months when NCP (Navigational Control Point) controls, and 16 months when Other (Delta requirements, flood control release, Delta exports or Sacramento River diversions) control.

Figure II.5.2
Sacramento River Flow Below Keswick Dam

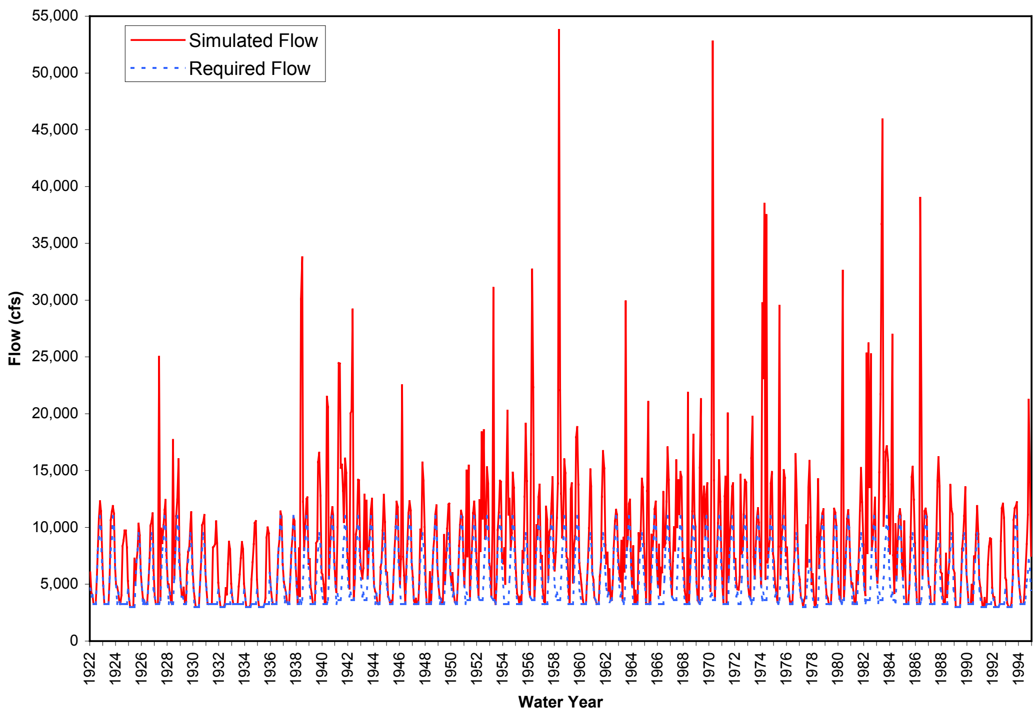

Figure II.5.2 shows the simulated and minimum instream required flows in the Sacramento River below Keswick Dam. The minimum required flows (Fish releases and temperature control flows) tend to control the releases from Keswick Dam in the dry years.

II.6. American River

Figure II.6.1
Folsom Lake Storage

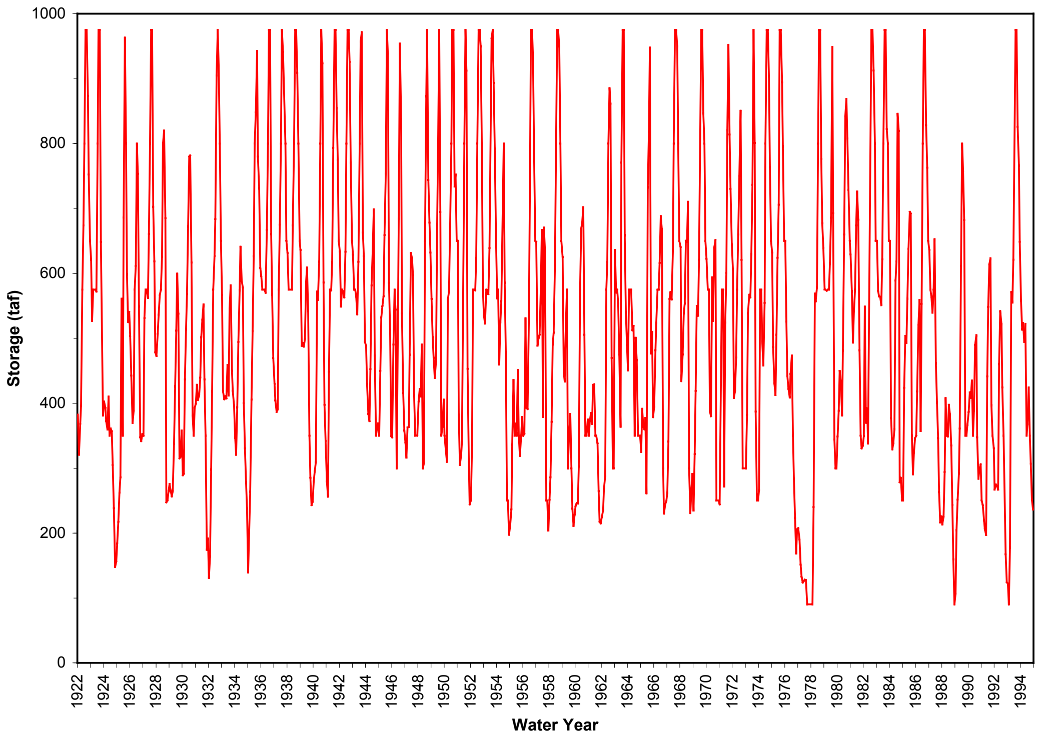

Figure II.6.1 shows Folsom Lake storage. In most months in dry years, Folsom Lake release is controlled by the fish release flows at Nimbus.

Table II.6.1
Folsom Lake Release Control

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Carryover Storage, taf
1922	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	650
1923	Other	Other	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	Other	381
1924	Other	Nimbus	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	156
1925	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	541
1926	Other	Other	Nimbus	Nimbus	Other	Nimbus	Other	Nimbus	Other	Other	Nimbus	Nimbus	352
1927	Other	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	478
1928	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	264
1929	Other	Other	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Other	Other	Nimbus	Nimbus	358
1930	Other	Nimbus	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	393
1931	Other	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	192
1932	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	650
1933	Other	Other	Nimbus	Nimbus	Nimbus	Other	Other	Nimbus	Other	Other	Other	Other	396
1934	Other	Other	Nimbus	Nimbus	Other	Nimbus	Other	Nimbus	Other	Nimbus	Nimbus	Other	238
1935	Other	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Nimbus	Other	Other	Other	609
1936	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	470
1937	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Nimbus	Other	Other	Other	650
1938	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1939	Nimbus	Other	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	248
1940	Other	Other	Nimbus	Other	Other	Other	Other	Other	Nimbus	Other	Other	Other	342
1941	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	650
1942	Nimbus	Other	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	Other	650
1943	Nimbus	Other	Other	Other	Other	Other	Other	Nimbus	Nimbus	Other	Other	Other	494
1944	Nimbus	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	369
1945	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Other	Other	Other	Other	Other	349
1946	Other	Nimbus	Other	Other	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	358
1947	Other	Other	Nimbus	Nimbus	Nimbus	Nimbus	Other	Nimbus	Other	Other	Other	Other	350
1948	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Nimbus	632
1949	Other	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Nimbus	405
1950	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Nimbus	Other	650
1951	Other	Other	Other	Other	Other	Other	Other	Other	Nimbus	Other	Other	Nimbus	244
1952	Other	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	574
1953	Other	Nimbus	Other	Other	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	650
1954	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	Other	Other	Nimbus	198
1955	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Nimbus	379
1956	Other	Nimbus	Other	Other	Other	Nimbus	Nimbus	Other	Other	Other	Other	Other	650
1957	Nimbus	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Nimbus	204
1958	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	650
1959	Nimbus	Other	Nimbus	Nimbus	Other	Other	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	229
1960	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Nimbus	375
1961	Other	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Nimbus	Nimbus	Nimbus	Nimbus	215
1962	Nimbus	Nimbus	Nimbus	Other	Other	Nimbus	Other	Nimbus	Nimbus	Other	Other	Other	300
1963	Nimbus	Other	Other	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	490
1964	Other	Other	Other	Other	Other	Nimbus	Other	Nimbus	Other	Other	Other	Other	350
1965	Other	Nimbus	Other	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	379
1966	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	249
1967	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1968	Other	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Nimbus	Nimbus	Nimbus	291
1969	Other	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1970	Other	Other	Other	Other	Other	Other	Other	Nimbus	Other	Other	Other	Other	250
1971	Other	Nimbus	Other	Other	Other	Nimbus	Other	Nimbus	Nimbus	Other	Other	Other	644
1972	Other	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Other	300
1973	Other	Nimbus	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	250
1974	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1975	Nimbus	Other	Nimbus	Other	Other	Other	Nimbus	Other	Other	Other	Other	Other	650
1976	Other	Other	Other	Nimbus	Other	Nimbus	Nimbus	Other	Other	Nimbus	Other	Nimbus	206
1977	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	H Street	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	90
1978	Nimbus	Other	H Street	Other	Other	Other	Other	Other	Other	Other	Other	Nimbus	639
1979	Other	Other	Nimbus	Other	Other	Other	Nimbus	Nimbus	Other	Other	Other	Other	300
1980	Nimbus	Nimbus	Nimbus	Other	Other	Other	Nimbus	Nimbus	Nimbus	Other	Other	Other	650
1981	Nimbus	Other	Nimbus	Nimbus	Other	Other	Nimbus	Nimbus	Other	Other	Nimbus	Nimbus	334
1982	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1983	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1984	Other	Other	Other	Other	Other	Other	Other	Nimbus	Other	Other	Other	Other	250
1985	Other	Nimbus	Nimbus	Other	Nimbus	Nimbus	Other	Nimbus	Other	Nimbus	Nimbus	Nimbus	346
1986	Other	Other	Nimbus	Other	Other	Other	Other	Other	Other	Other	Other	Other	650
1987	Other	Other	Nimbus	Nimbus	Other	Nimbus	Other	Other	Nimbus	Nimbus	Nimbus	Other	226
1988	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Other	Other	Nimbus	Nimbus	Nimbus	90
1989	H Street	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Other	Other	Other	Other	367
1990	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Other	Other	Nimbus	Nimbus	Nimbus	306
1991	Other	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Other	Other	Other	Nimbus	331
1992	Other	Nimbus	Nimbus	Nimbus	Nimbus	Nimbus	Other	Nimbus	Other	Other	Nimbus	Nimbus	124
1993	Nimbus	Other	Nimbus	Other	Other	Other	Other	Other	Other	Other	Nimbus	Other	649
1994	Other	Other	Nimbus	Nimbus	Nimbus	Other	Nimbus	Nimbus	Other	Nimbus	Nimbus	Nimbus	236

Table II.6.1 shows the factors controlling Folsom Lake release. In the May 1928 to October 1934 dry period, there are 33 months when Nimbus minimum required flow controls and 33 months when other (American River diversions, Delta required flows, Delta exports, or flood control releases) controls.

Figure II.6.2
American River Flow at Nimbus Dam

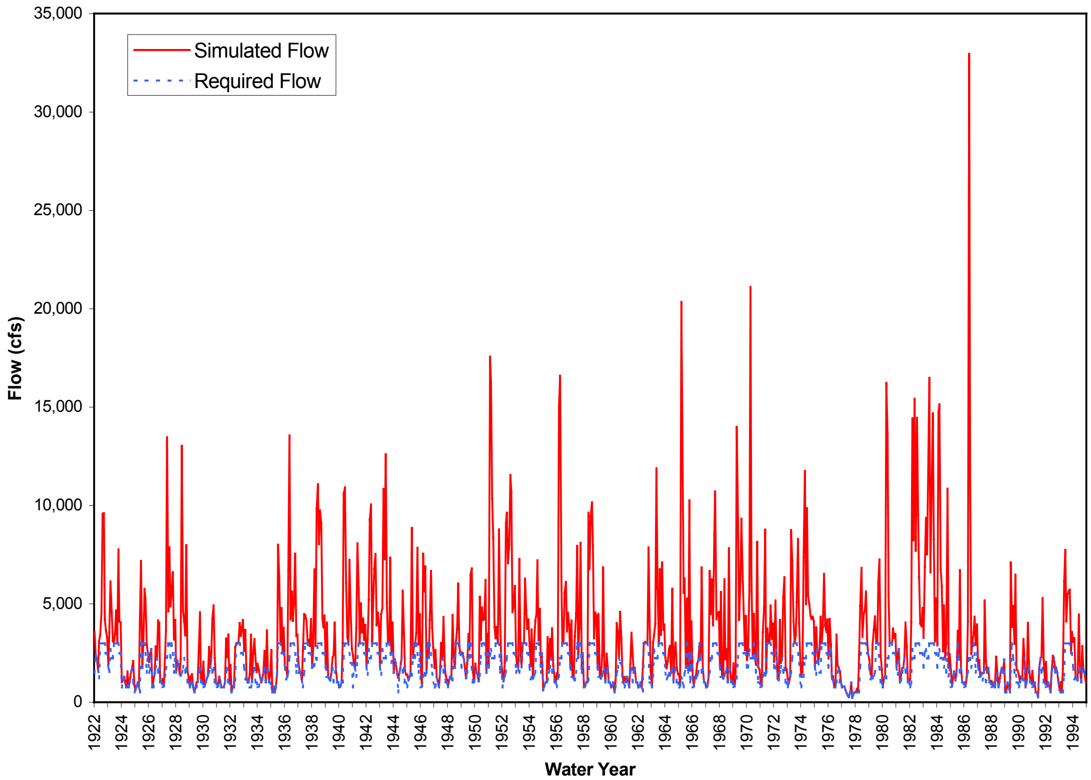

Figure II.6.2 shows the simulated and minimum instream required flows in the American River below Nimbus Dam. The minimum instream flows at Nimbus tend to control Folsom reservoir operations in some months of most years.

Figure II.6.3
American River Flow at H St

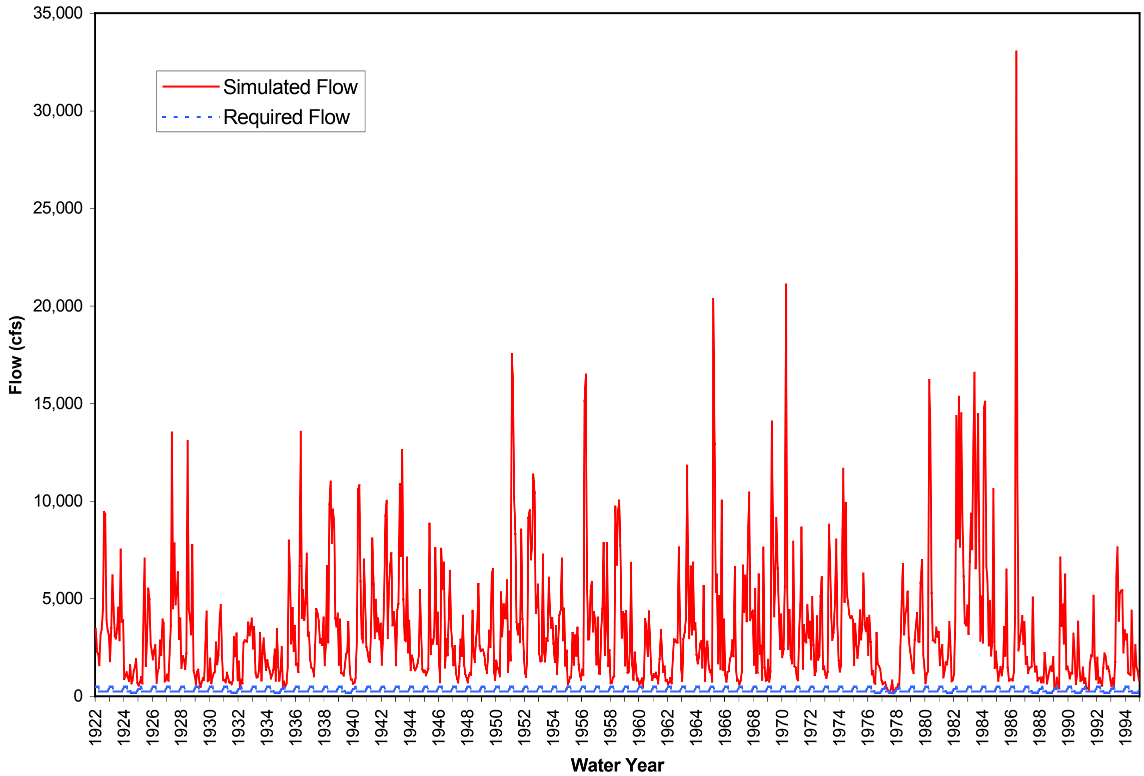

Figure II.6.3 shows the simulated and minimum instream required flows in the American River at H Street. The minimum instream flows at Nimbus tend to control Folsom reservoir operations in some months of most years.

II.7. Feather River

Figure II.7.1
Lake Oroville Storage

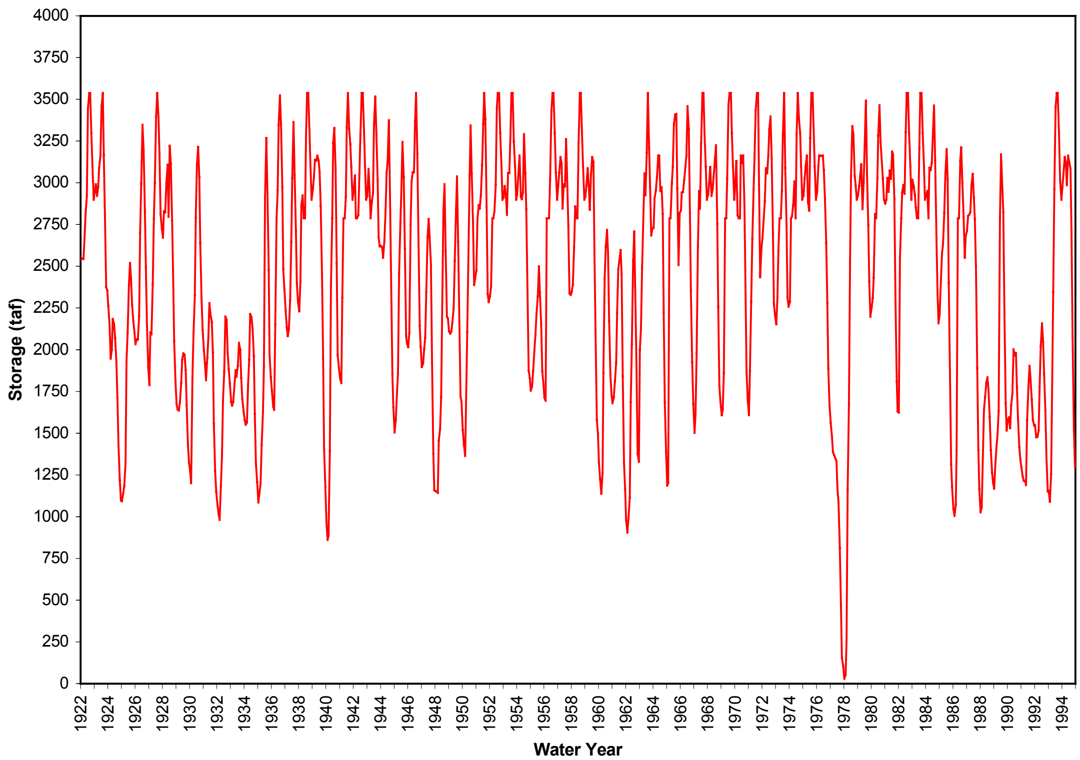

Figure II.7.1 shows Lake Oroville storage. The lowest storage value is 30 taf.

Figure II.7.2
Feather River Flow Below Thermalito

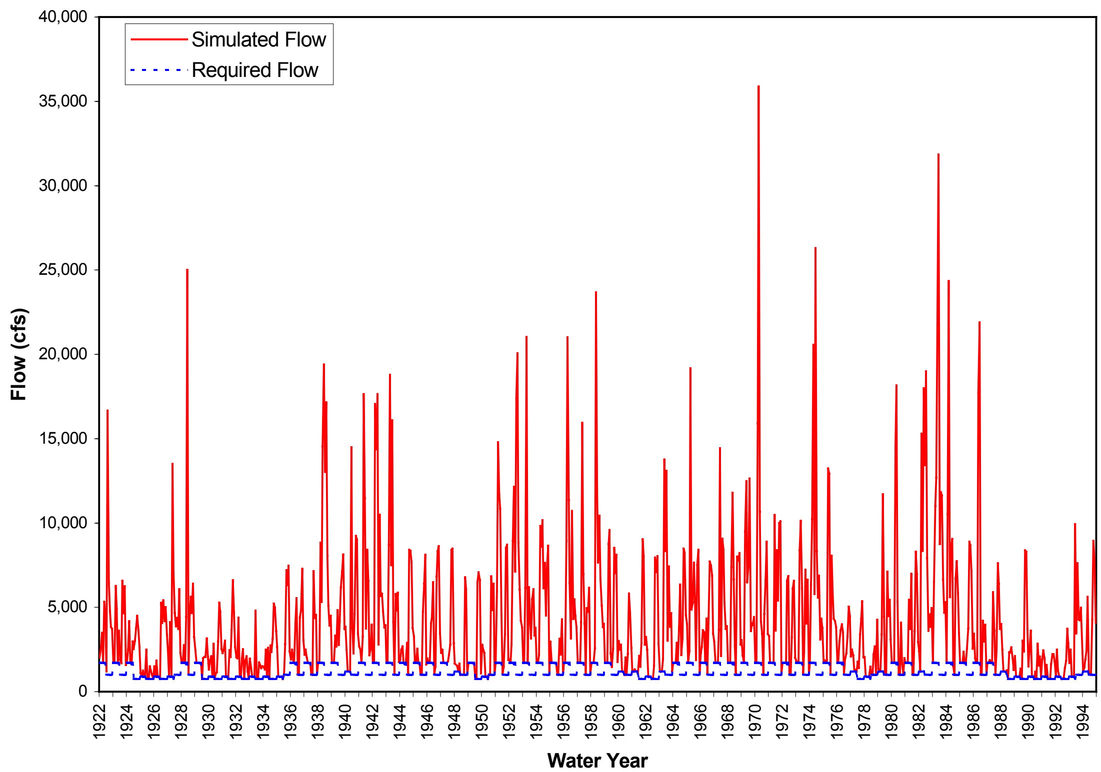

Figure II.7.2 shows simulated and minimum instream required flows in the Feather River below Thermalito Diversion Dam. The simulated flows are almost always higher than the minimum required flows. The river's minimum instream flow does not control Oroville reservoir operations in most years.

II.8. Stanislaus/San Joaquin Rivers

Figure II.8.1
New Melones Reservoir Storage

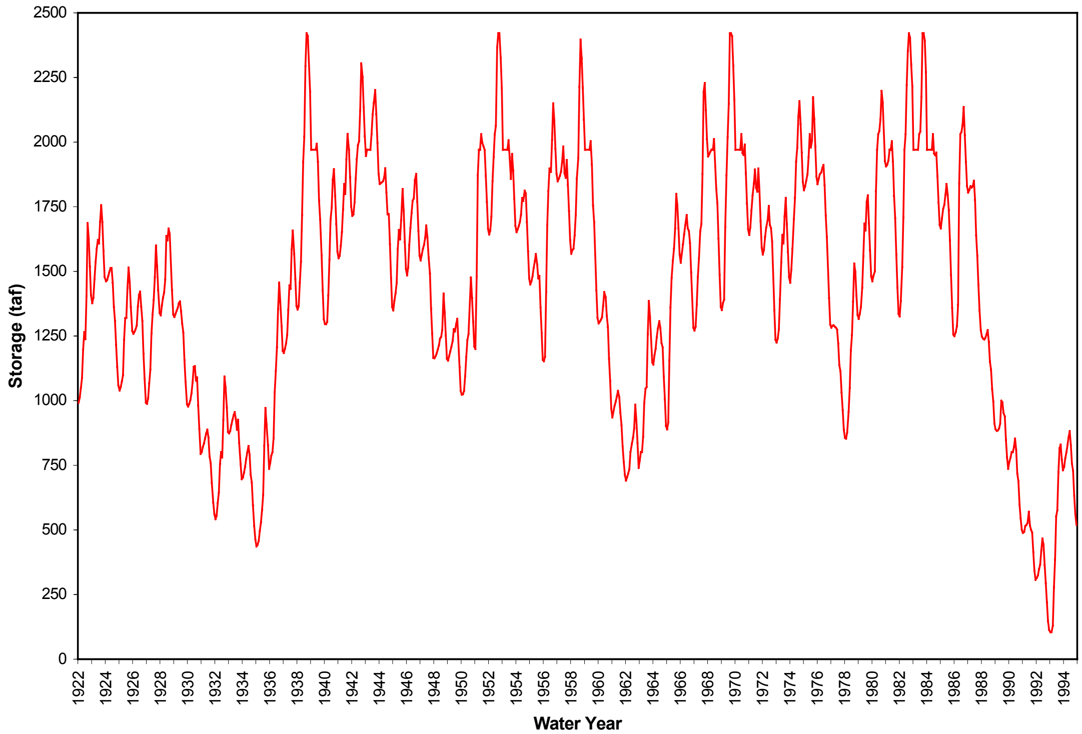

Figure II.8.1 shows New Melones Reservoir storage.

Figure II.8.2
Stanislaus River Flow Below Goodwin Dam

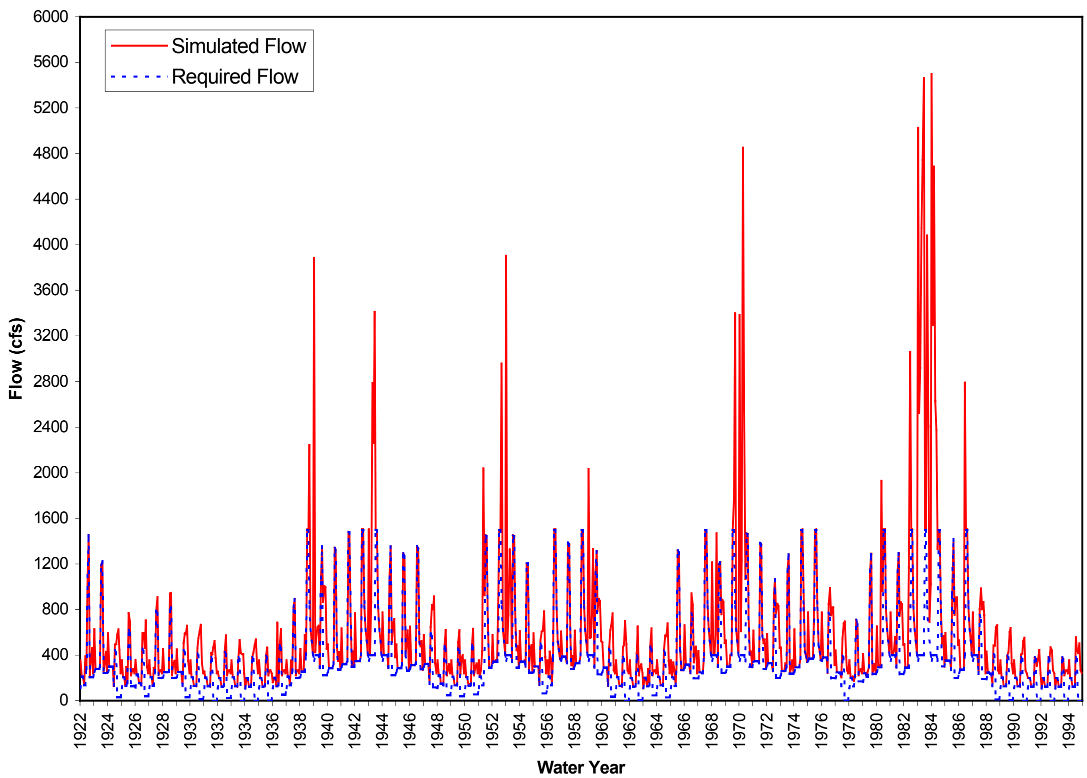

Figure II.8.2 shows the simulated and minimum instream required flows in the Stanislaus River at Goodwin. The minimum instream flows tend to control New Melones releases at Goodwin Dam in some months of most years.

Figure II.8.3
San Joaquin River simulated flow at Vernalis

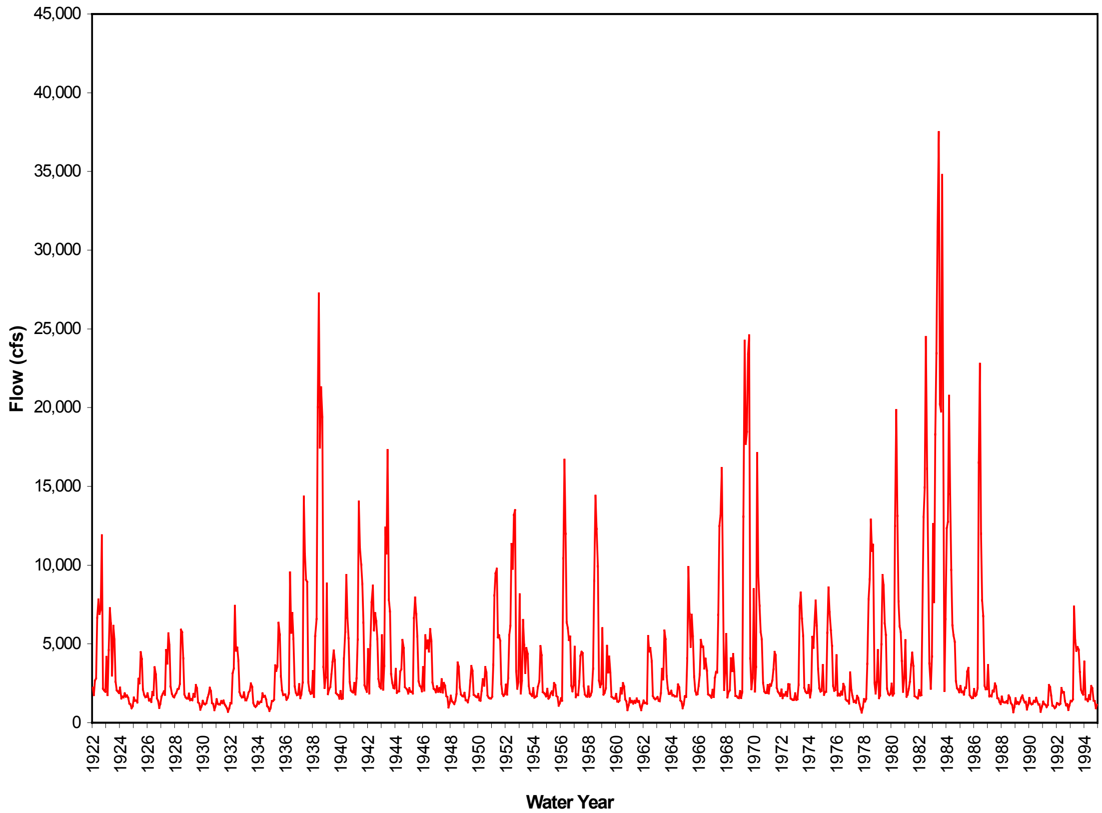

Figure II.8.3 shows the simulated San Joaquin River flow at Vernalis.

II.9. Delta

Figure II.9.1
Total Required Delta Outflow

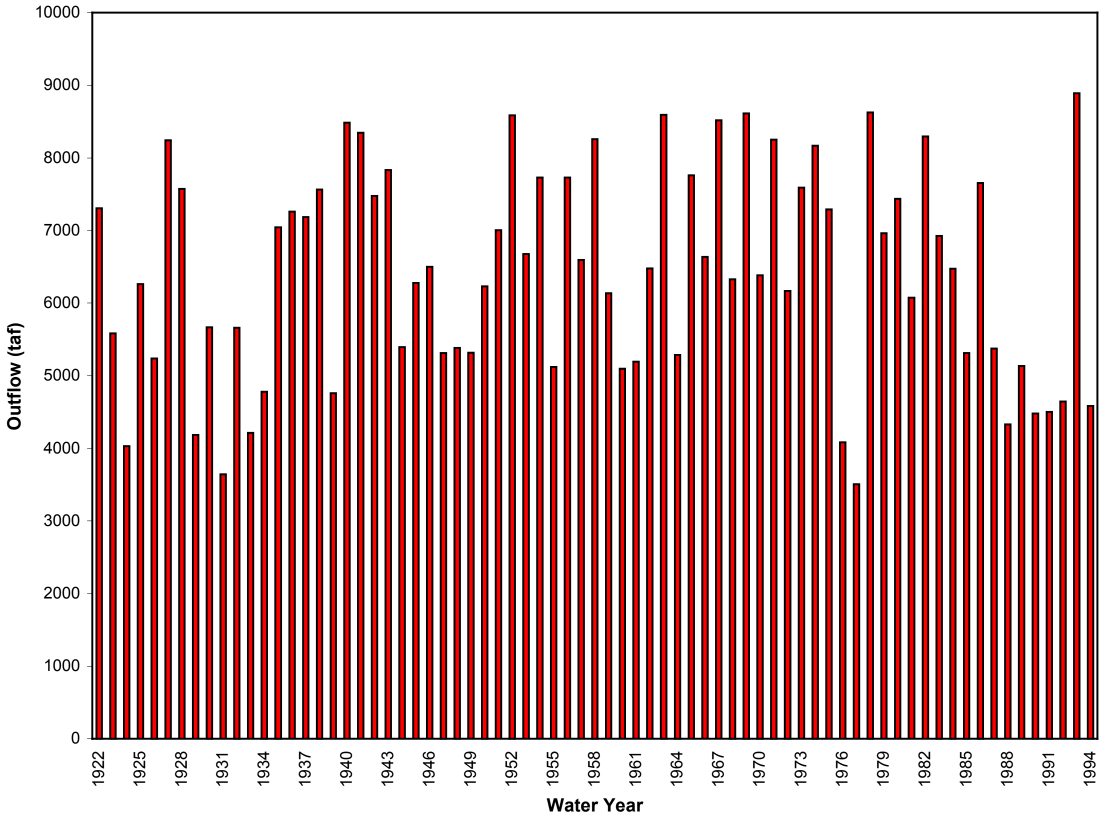

Figure II.9.1 shows the total annual required Delta outflow. The total required outflow is the flow needed to meet X2 and minimum outflow requirements. The average annual total required Delta outflow is 6414 taf.

Figure II.9.2
Total Delta Outflow

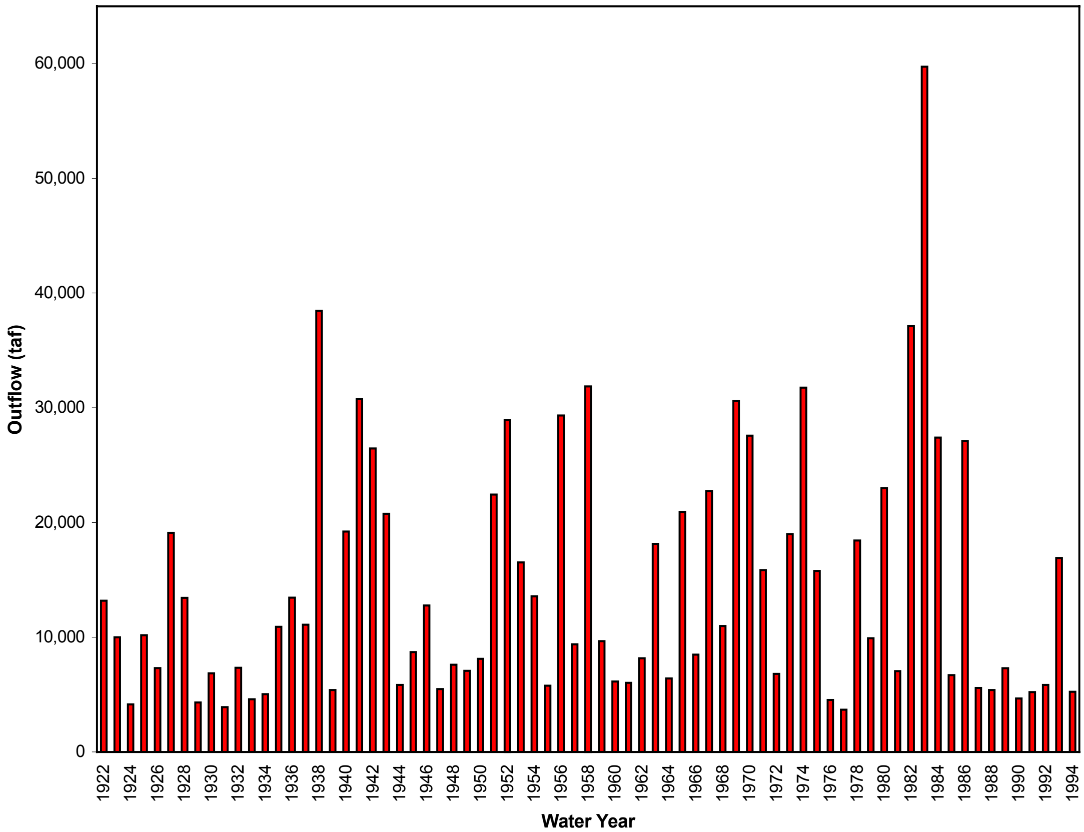

Figure II.9.2 shows annual total Delta outflow. The average annual total Delta outflow is 14319 taf.

Figure II.9.3
X2 Position

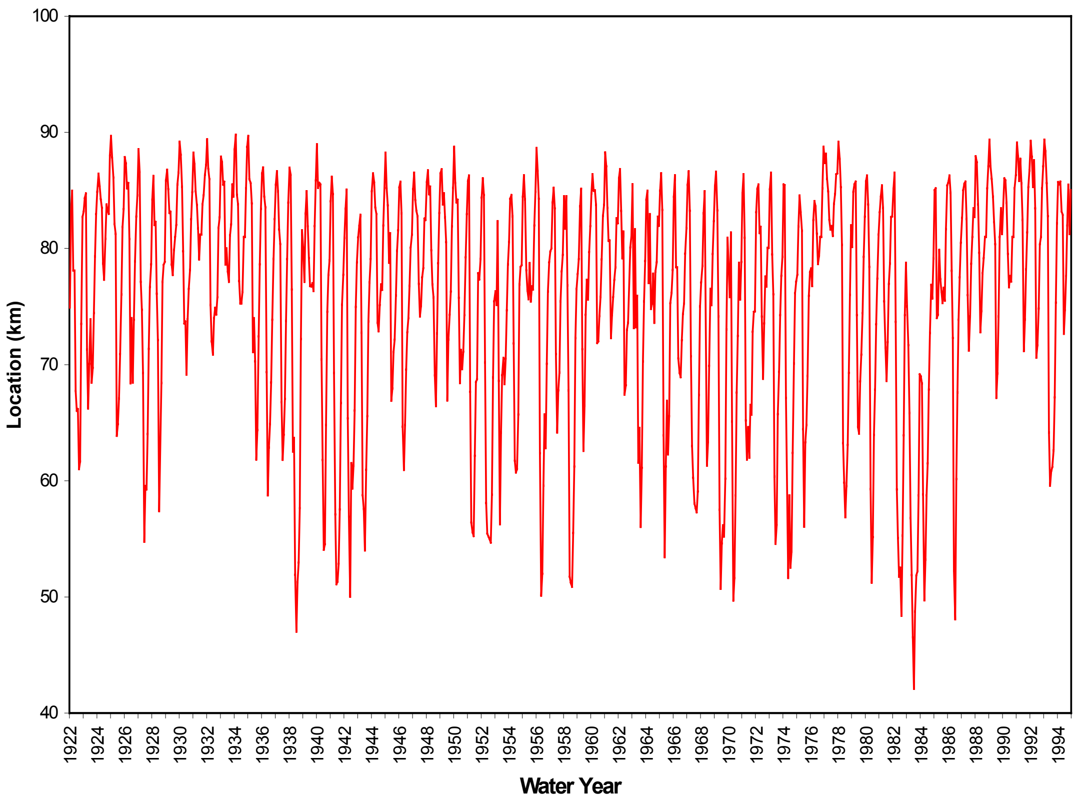

Figure II.9.3 shows the monthly resulting X2 position. The X2 position ranges from 42 km to 90 km.

Figure II.9.4
Average Monthly QWEST Flows

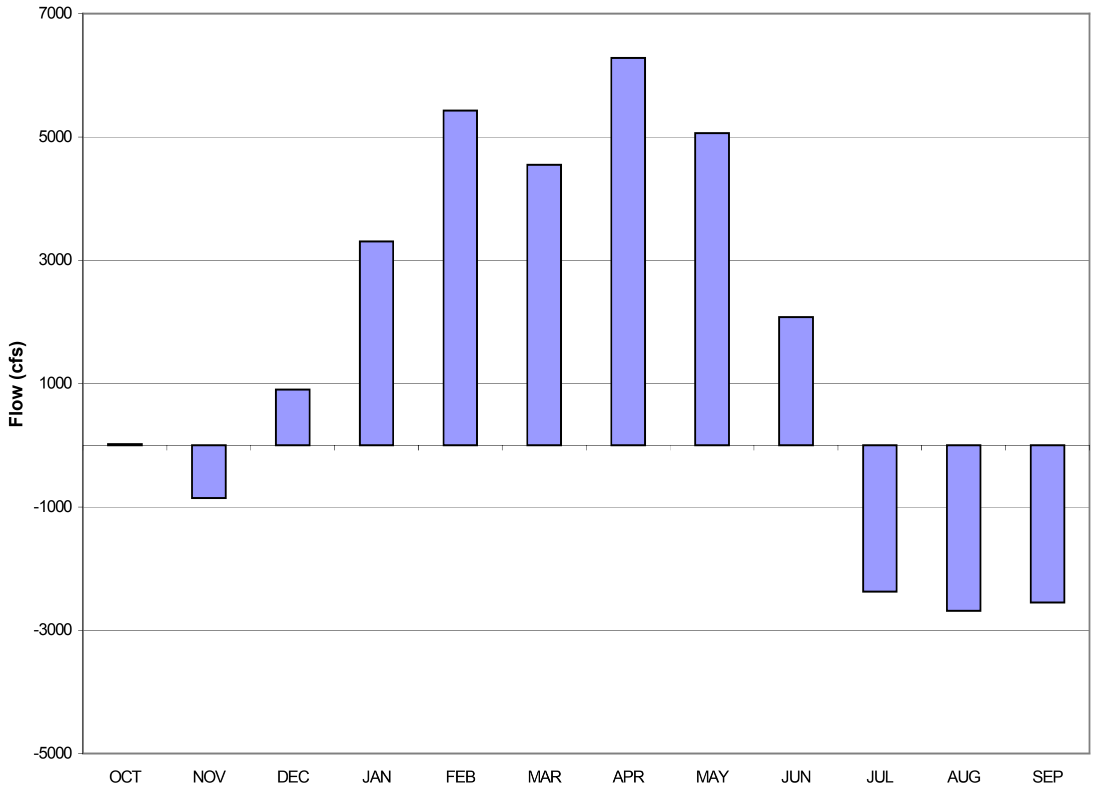

Figure II.9.4 shows the average monthly QWEST flows.

II.10. South-of-Delta

Figure II.10.1
SWP San Luis Reservoir Storage

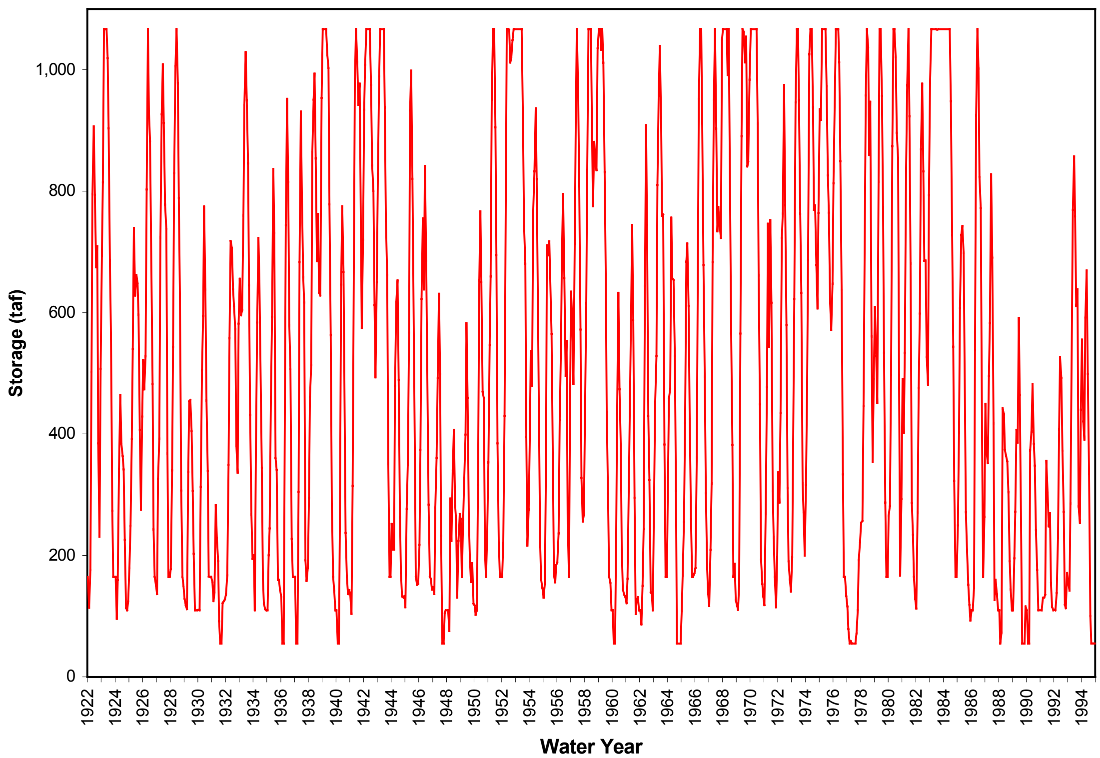

Figure II.10.1 shows SWP San Luis reservoir storage. The low points shown do not include EWA's storage debt owed to the SWP. The September end-of-month storage in SWP San Luis includes EWA debt payback.

Figure II.10.2
CVP San Luis Reservoir Storage

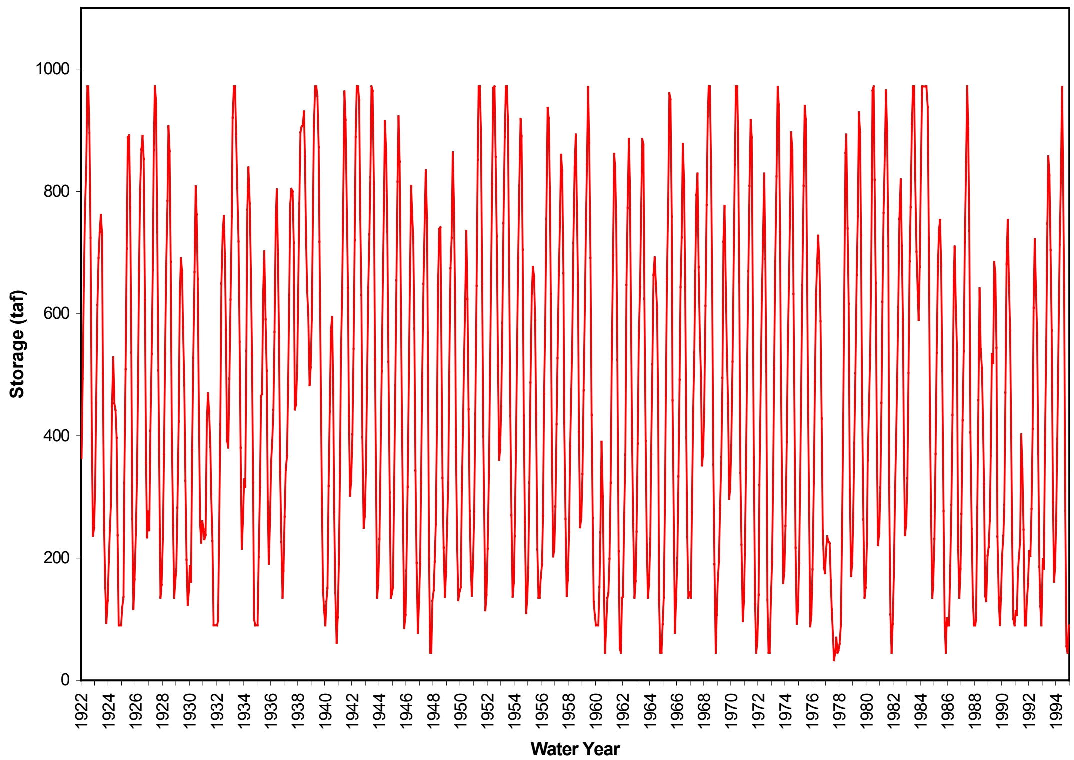

Figure II.10.2 shows CVP San Luis reservoir storage. The low points shown do not include EWA's storage debt owed to the projects. The September end-of-month storage in CVP San Luis Reservoir includes EWA debt payback.